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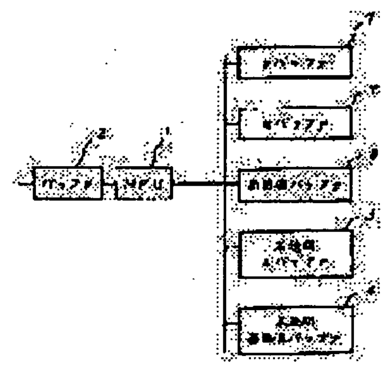
(54) THREE-DIMENSIONAL IMAGE DISPLAY PROCESSING METHOD

(57)Abstract:
PURPOSE: To correctly display a transparent object even when the object is multiplexed.
CONSTITUTION: In a three-dimensional image display processing method for displaying the transparent object by means of alpha blending method, an opaque Z buffer 3 storing the Z value of a latest opaque object and an opaque picture element value buffer 4 storing the picture element value of the latest opaque object are provided. The Z value of the object to be displayed is compared with the Z value in the opaque Z buffer 3 and when the object to be displayed is further than the latest opaque object, the picture element value of the object to be displayed will not be the object of picture element calculation. When the object to be displayed is closer than the latest opaque object and the object to be displayed is higher in speed than the latest object in a Z buffer 7, the picture element value is restored from the picture element value in a picture element value buffer 8, that in the opaque picture element value buffer 4 and transparency in a α, buffer 9 and a new picture element value is calculated based on the picture element of the object to be displayed, the tansparency in the α buffer 9 and the restored picture element.



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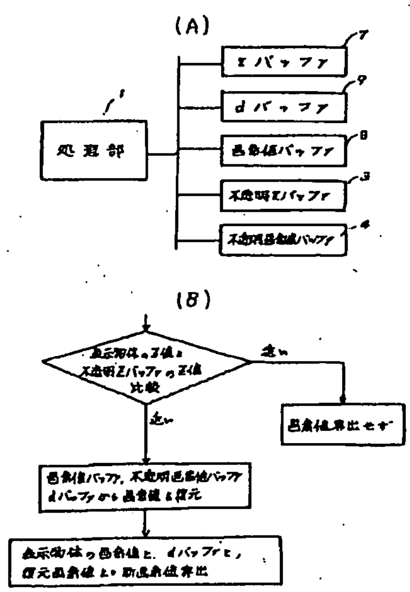
(54)【発明の名称】　三次元画像表示処理方法

(57)【要約】

【目的】　アルファ・ブレンディング法により透明物体を表示するための三次元画像表示処理方法に関し、物体が多重化しても、透明物体を正しく表示することを目的とする。

【構成】　アルファ・ブレンディング法により透明物体を表示するための三次元画像表示処理方法において、最近の不透明物体のＺ値を格納する不透明Ｚバッファ３と、最近の不透明物体の画素値を格納する不透明画素値バッファ４とを設け、表示しようとする物体のＺ値と、不透明Ｚバッファ３のＺ値とを比較し、表示しようとする物体が最近の不透明物体より遠い場合には、表示しようとする物体の画素値を画素値算出の対象とせず、表示しようとする物体が最近の不透明物体より近い場合で且つ該表示しようとする物体がＺバッファ７の最近の物体より遠い場合には、画素値バッファ８の画素値と、不透明画素値バッファ４の画素値と、αバッファ９の透明度とから画素値を復元し、表示しようとする物体の画素値と、αバッファ９の透明度と、復元画素値とに基づいて新画素値を算出する。

本発明の原理図



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【特許請求の範囲】

【請求項1】 各画素毎の視点からの最近の物体の奥行位置であるZ値を格納するZバッファ（7）と、該各画素毎に該最近の物体の透明度を格納するαバッファ（9）と、各画素の画素値を格納する画素値バッファ（8）と、処理部（1）とを有し、表示しようとする物体のZ値と該Zバッファ（7）のZ値との比較により隠面消去を行うとともに、該αバッファ（9）の透明度と、該表示しようとする物体の画素値とに基づいて新画素値を算出して、透明物体の表示を行う画像処理装置において、該最近の不透明物体のZ値を格納する不透明Zバッファ（3）と、該最近の不透明物体の画素値を格納する不透明画素値バッファ（4）とを設け、表示しようとする物体のZ値と、該不透明Zバッファ（3）のZ値とを比較し、該表示しようとする物体が該最近の不透明物体より遠い場合には、該表示しようとする物体の画素値を画素値算出の対象とせず、該表示しようとする物体が該最近の不透明物体より近い場合で且つ該表示しようとする物体が該Zバッファ（7）の該最近の物体より遠い場合には、該画素値バッファ（8）の画素値と、該不透明画素値バッファ（4）の画素値と、該αバッファ（9）の透明度とから該画素値を復元し、該表示しようとする物体の画素値と、該αバッファ（9）の透明度と、該復元画素値とに基づいて新画素値を算出することを特徴とする三次元画像表示処理方法。

【請求項2】 前記表示しようとする物体が透明物体の場合に、前記表示しようとする物体の画素値と透明度と、前記αバッファ（9）の透明度と、前記復元画素値とに基づいて新画素値を算出し、前記表示しようとする物体の透明度と前記αバッファ（9）の透明度とから新透明度を算出し、前記新画素値と前記新透明度と前記不透明画素値バッファ（4）の画素値とに基づいて新画素値を算出することを特徴とする請求項1の三次元画像表示処理方法。

【請求項3】 前記表示しようとする物体が前記最近の不透明物体より近い場合で且つ前記表示しようとする物体が該Zバッファ（7）の前記最近の物体より近い場合には、前記表示しようとする物体が透明物体の場合に、前記画素値バッファ（8）の画素値と、前記不透明画素値バッファ（4）の画素値と、前記αバッファ（9）の透明度とから前記画素値を復元し、前記表示しようとする物体の画素値と透明度と、前記αバッファ（9）の透明度と、前記復元画素値とに基づいて新画素値を算出し、前記表示しようとする物体の透明度と前記αバッファ（9）の透明度とから新透明度を算出し、前記新画素値と前記新透明度と前記不透明画素値バッファ（4）の画素値とに基づいて新画素値を算出することを特徴とする請求項1の三次元画像表示処理方法。

【発明の詳細な説明】

【0001】（目次）

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【0002】

【産業上の利用分野】本発明は、アルファ・ブレンディング法により透明物体を表示するための三次元画像表示処理方法に関する。

【0003】近年のハードウェアの進歩に伴い、コンピュータによる高速な三次元画像表示が可能となってきた。この基礎技術としてZバッファ法が知られている。Zバッファ法は、三次元空間上に配置された物体をある視点から見た場合の物体の重なりによる隠面を消去する方法の一つであり、特に高速な三次元画像表示のためには不可欠な技術である。

【0004】図8はZバッファ法の説明図である。

【0005】Zバッファ法は、図8（C）、（D）に示すように、画面の各画素毎に、視点からの最近の図形の奥行方向の位置であるZ値を格納するZバッファ7と、その図形の画素値を格納する画素値バッファ8とを用いる。

【0006】そして、図8（A）に示すように、表示しようとする図形（ここでは三角形を例にとる）の各画素のZ値（視点からの奥行方向の位置）と、図8（B）に示すように、その図形の各画素の画素値を計算し、そのZ値がZバッファ7の対応する画素のZ値より、視点に近ければ、図8（E）、（F）のように、画素値バッファ8とZバッファ7の対応する画素の内容を、表示しようとする図形中の画素のZ値と画素値で置き換え（図8（E）、（F）の太線部分）、遠ければ、Z値と画素値の置き換えを行わないことにより、最終的に視点から見える表面或いは表面の一部だけを表示する方法である。

【0007】このZバッファ法の欠点は、物体を不透明と考え、その前後関係を判定するだけであるため、透明物体が表示出来ないことである。

【0008】このため、透明物体も三次元表示できる三次元表示処理技術が求められる。

【0009】

【従来の技術】図9は従来技術の説明図である。

【0010】透明物体を表示するものとして、図9に示すように、画素値バッファ8の画素毎に、表示すべき物体に対応する画素の情報（画素値、Z値、透明度）を、出現順にリストとして保存しておき、全ての物体の情報が集まったところでZ値でソートして、不透明物体が現れるまで、透明度を考慮して画素値を確定する方法があ

る。

【0011】この方法によれば、透明物体を含めた三次元画像表示が正しく行えるが、リストの作成には、膨大なメモリが必要であり、しかもリストをZ値でソートする必要があり、膨大な演算が必要となり、ハードウェア化もしにくいという欠点がある。

【0012】そこで、透明物体を含めた三次元画像表示は正しく行えなくてもよいが、高速に透明感が得られる方法として、アルファ・ブレンディング法が提案されている。この方法は、Zバッファ法で隠面消去を行うが、Zバッファの他に物体の透明度を格納するαバッファを用意し、透明物体を表示する際に、それまで画素値バッファ8に格納されている対応する画素の画素値に、その物体の透明度に応じた透明物体の画素値を加えていくものである。

【0013】図10及び図11は従来のアルファ・ブレンディング法の説明図である。

【0014】図10（A）に示すように、Zバッファ7と画素値バッファ8の他に、αバッファ9を設け、入力バッファ2に入力される表示データを、プロセッサ（MPU）1がアルファ・ブレンディング処理する。

【0015】例えば、図10（B）のように、Z値がZ1の透明物体（透明度a＝0．5、画素値D＝8）が表示されている時に、Z値がZ2の不透明物体（透明度a＝0．0、画素値D＝16）を表示する場合を考える。

【0016】この時のZバッファ7、αバッファ9、画素値バッファ8の内容は、図10（B）のように、Z値がZ1の透明物体のものとなっている。Z値がZ2の不透明物体は、一画素がZ値がZ1の透明物体と重なるが、この時ブレンディング後の画素値Dbは、次の（1）式で計算される。

【0017】

【数1】

$$Db = Dt \times (1 - at) + Di \times at$$

【0018】ここで、Dtは透明物体の画素値、atは透明物体の透明度、Diは不透明物体の画素値である。

【0019】透明物体と不透明物体が重ならない部分は、透明物体の画素値、不透明物体の画素値がそのまま表示されればよいので、アルファ・ブレンディング後のZバッファ7、αバッファ9、画素値バッファ8の内容は、図10（C）に示すように変化する。

【0020】これを処理フローで示すと、図11のようになる。

【0021】入力バッファ2から表示すべき図形の画素情報（X、Y、Z、α、D）を読み込み、Zバッファ7、αバッファ9、画素値バッファ8のX、Yに対応する位置の内容を読出し、各々Z'、α'、D'とする。プロセッサ1は、ZとZ'とを比較し、ZとZ'とのうち視点に近い方のZ値をZ"とし、α値をα1とし、D値をD1とし、ZとZ'とのうち視点に遠い方のα値をα2とし、D値をD2とする。そして、更新透明度α"を次の（2）式により計算する。

【0022】

【数2】

$$\alpha'' = \alpha_1 + (\alpha_1 \times \alpha_2)$$

【0023】次に、前述の（1）式のDtにD1を、atにα1を、DiにD2を代入し、D"を得る。そして、Zバッファ7、αバッファ9、画素値バッファ8のX、Yに対応する位置の内容を、Z"、α"、D"で更新する。

【0024】このようにして、ガラス等の透明物体を介した不透明物体の三次元表示が可能となる。

【0025】

【発明が解決しようとする課題】図12、図13、図14は従来のアルファ・ブレンディング技術の問題点説明図である。

【0026】図10（C）のブレンディングが行われた後、Z値がZ3である不透明物体が、図12（A）のように、Z値がZ1である透明物体とZ値がZ2である不透明物体との間に、挿入される場合、図12（B）のように、Z値がZ2である不透明物体との後に、配置される場合がある。これらの場合に、図11の従来のアルファ・ブレンディング法を適用すると、Zバッファ7、αバッファ9、画素値バッファ8の内容と、Z値がZ3である不透明物体の画素情報の内容とからブレンディング処理され、図13（A）に示すように、ブレンディングされた画素値は、Z値がZ1である物体、Z2である物体、Z3である物体の全ての対応する画素値が反映されたものとなる。

【0027】ところで、図12（A）の本来の状態は、図13（B）のように、Z値がZ3である不透明物体によって、Z値がZ2である不透明物体が隠され、見えない状態により、図12（B）の本来の状態は、図14（A）のように、Z値がZ2である不透明物体によって、Z値がZ3である不透明物体が隠され、見えない状態にある。

【0028】従って、正しい表示結果は、図12（A）では、Z値がZ1である透明物体と、Z値がZ3である不透明物体の画素値から、図14（B）のように決定されるべきであり、図12（B）では、Z値がZ1である透明物体と、Z値がZ2である不透明物体の画素値から、図14（C）のように決定されるべきである。

【0029】このように、従来のアルファ・ブレンディング法では、ハードウェア化を意識した高速性に重点を置いているため、物体の順番にかかわらず、1つの物体しかないと見なして、処理するため、物体が多重化すると、透明物体を正しく表示できないという問題があった。

【0030】従って、本発明は、物体が多重化しても、透明物体を正しく表示することができる三次元画像表示

処理方法を提供することを目的とする。

【0031】

【課題を解決するための手段】図1は本発明の原理図である。

【0032】本発明の請求項1は、各画素毎の視点からの最近の物体の奥行位置であるZ値を格納するZバッファ7と、該各画素毎に該最近の物体の透明度を格納するαバッファ9と、各画素の画素値を格納する画素値バッファ8と、処理部1とを有し、表示しようとする物体のZ値と該Zバッファ7のZ値との比較により隠面消去を行うとともに、該αバッファ9の透明度と、該表示しようとする物体の画素値とに基づいて新画素値を算出して、透明物体の表示を行う画像処理装置において、該最近の不透明物体のZ値を格納する不透明Zバッファ3と、該最近の不透明物体の画素値を格納する不透明画素値バッファ4とを設け、表示しようとする物体のZ値と、該不透明Zバッファ3のZ値とを比較し、該表示しようとする物体が該最近の不透明物体より遠い場合には、該表示しようとする物体の画素値を画素値算出の対象とせず、該表示しようとする物体が該最近の不透明物体より近い場合で且つ該表示しようとする物体が該Zバッファ7の該最近の物体より遠い場合には、該画素値バッファ8の画素値と、該不透明画素値バッファ4の画素値と、該αバッファ9の透明度とから該画素値を復元し、該表示しようとする物体の画素値と、該αバッファ9の透明度と、該復元画素値とに基づいて新画素値を算出することを特徴とする。

【0033】本発明の請求項2は、請求項1において、前記表示しようとする物体が透明物体の場合に、前記表示しようとする物体の画素値と透明度と、前記αバッファ9の透明度と、前記復元画素値とに基づいて新画素値を算出し、前記表示しようとする物体の透明度と前記αバッファ9の透明度とから新透明度を算出し、前記新画素値と前記新透明度と前記不透明画素値バッファ4の画素値とに基づいて新画素値を算出することを特徴とする。

【0034】本発明の請求項3は、請求項1において、前記表示しようとする物体が前記最近の不透明物体より近い場合で且つ前記表示しようとする物体が該Zバッファ7の前記最近の物体より近い場合には、前記表示しようとする物体が透明物体の場合に、前記画素値バッファ8の画素値と、前記不透明画素値バッファ4の画素値と、前記αバッファ9の透明度とから前記画素値を復元し、前記表示しようとする物体の画素値と透明度と、前記αバッファ9の透明度と、前記復元画素値とに基づいて新画素値を算出し、前記表示しようとする物体の透明度と前記αバッファ9の透明度とから新透明度を算出し、前記新画素値と前記新透明度と前記不透明画素値バッファ4の画素値とに基づいて新画素値を算出することを特徴とする。

【0035】

【作用】透明物体と不透明物体の重なりを考察すると、不透明物体に関しては、いったん現れると、その視点から見た後ろの物体は全て見えない。即ち、表示される画像には、視点に一番近い不透明物体までの情報があればよい。そこで、本発明の請求項1では、最近の不透明物体のZ値を格納する不透明Zバッファ3と、該最近の不透明物体の画素値を格納する不透明画素値バッファ4とを設けた。

【0036】そして、後から表示される不透明物体が先に表示されている不透明物体より視点から遠い場合に、後の不透明物体の画素値をブレンディングしなければ、正しい透明物体の表示ができる。そこで、表示しようとする物体のZ値と、不透明Zバッファ3のZ値とを比較し、表示しようとする物体が最近の不透明物体より遠い場合には、表示しようとする物体の画素値を画素値算出の対象としないようにした。

【0037】又、後から表示される不透明物体が先に表示されている不透明物体より視点に近い場合に、ブレンディングされた画素値を再計算できれば、正しい透明物体の表示ができる。そこで、表示しようとする物体が最近の不透明物体より近い場合で且つ表示しようとする物体がZバッファ7の最近の物体より遠い場合には、画素値バッファ8の画素値と、不透明画素値バッファ4の画素値と、αバッファ9の透明度とから画素値を復元し、表示しようとする物体の画素値と、αバッファ9の透明度と、復元画素値とに基づいて新画素値を算出するようにした。

【0038】本発明の請求項2では、表示しようとする物体が透明物体の場合でも、この透明物体の透明度を考慮した多重の透明物体の表示ができる。

【0039】本発明の請求項2では、表示しようとする物体が透明物体で最も視点に近い場合でも、この透明物体の透明度を考慮した多重の透明物体の表示ができる。

【0040】

【実施例】（a）一実施例の説明

図2は本発明の一実施例構成図であり、図中、図1及び図10で示したものと同一のものは、同一の記号で示してある。

【0041】図2において、Zバッファ7、αバッファ9、画素値バッファ8、不透明Zバッファ3、不透明画素値バッファ4は、1つのメモリで構成されている。

【0042】図3、図4は本発明の一実施例の三次元画像処理フロー図であり、図5は本発明の一実施例の説明図、図6は不透明物体の後に挿入される場合の説明図、図7は透明物体と不透明物体の間に挿入される場合の説明図である。

【0043】①プロセッサ1は、入力バッファ2から表示すべき物体の画素情報（X、Y、Z、α、D）を読み込み、不透明Zバッファ3のX、Yに対応する位置の内

容を読み込み、Ｚｕとする。

【００４４】②プロセッサ１は、ＺとＺｕとを比較する。Ｚ＞Ｚｕなら、図５（Ａ）、図６のように、表示すべき物体が不透明物体の後（遠く）にあり、不透明物体で隠されるため、図６のように、全バッファ３、４、７、８、９の内容を変更せず、ステップ①に戻る。

【００４５】③表示すべき物体が不透明物体の後（遠く）になければ、プロセッサ１は、Ｚバッファ７、αバッファ９、画素値バッファ８、不透明画素値バッファ４のＸ、Ｙに対応する位置の内容を読み込み、それぞれＺ'、α'、Ｄ'、Ｄｕとする。更に、プロセッサ１は、ＺとＺ'とを比較する。Ｚ＞Ｚ'なら、図５（Ｂ）、（Ｃ）のように、表示すべき物体が透明物体と不透明物体の間にあるため、ステップ④に進み、Ｚ＜Ｚ'なら図５（Ｄ）、（Ｅ）のように、表示すべき物体が透明物体の前にあるため、ステップ⑥（図４のＢ）に進む。

【００４６】④表示すべき物体が透明物体と不透明物体の間にあるなら、先ず画素値を復元する。復元画素値Ｄ１を、画素値バッファ８のＤ'、不透明画素値バッファ４のＤｕ、αバッファ９のα'を用い、次の（３）式で計算する。

【００４７】

【数３】

$$D1=(D'-Du\times\alpha')/(1-\alpha')$$

【００４８】次に、プロセッサ１は、表示すべき物体の透明度αが「０」（不透明）でないかを判定する。αが「０」（不透明）でないと、表示すべき物体は透明の場合（図５（Ｃ）の場合）であるので、ステップ⑤（図４のＡ）に進む。

【００４９】一方、αが「０」（不透明）であると、表示すべき物体は不透明の場合（図５（Ｂ）の場合）であるので、図７に示すように、復元画素値Ｄ１、αバッファ９のα'、表示すべき物体の画素値Ｄを用いて、次の（４）式で新画素値Ｄ"を計算する。

【００５０】

【数４】

$$D''=D_1\times(1-\alpha')+D\times\alpha'$$

【００５１】この式は、（１）式と同一である。そして、画素値バッファ８と、不透明Ｚバッファ３と、不透明画素値バッファ４のＸ、Ｙに対応する位置の内容を、それぞれ新画素値Ｄ"、Ｚ，Ｄで更新し、ステップ①に戻る。

【００５２】⑤αが「０」（不透明）でないと、表示すべき物体は透明の場合であるので、図５（Ｃ）に示すように２つ透明物体が並ぶため、新画素値Ｄ"と統合透明度α"を計算する。

【００５３】先ず、復元画素値Ｄ１、αバッファ９のα'、表示すべき物体の画素値Ｄ、透明度αを用い、新画素値Ｄ"を次の（５）式で計算する。

【００５４】

【数５】

$$D''=D_1\times(1-\alpha')+D\times(1-\alpha)\times\alpha'$$

【００５５】次に、αバッファ９のα'、表示すべき物体の透明度αを用い、統合透明度α"を次の（６）式で計算する。

【００５６】

【数６】

$$\alpha''=\alpha\times\alpha'$$

【００５７】更に、新画素値Ｄ"、統合透明度α"、不透明画素値バッファ４の画素値Ｄｕを用い、新画素値Ｄ"を次の（７）式で計算する。

【００５８】

【数７】

$$D''=D''\times(1-\alpha'')+Du\times\alpha''$$

【００５９】そして、αバッファ９、画素値バッファ８のＸ、Ｙに対応する位置の内容を、それぞれ統合透明度α"、新画素値Ｄ"で更新して、ステップ①に戻る。

【００６０】⑥ステップ③で、表示すべき物体が透明物体の前にある場合には、プロセッサ１は、表示すべき物体の透明度αが「０」（不透明）でないかを判定する。αが「０」（不透明）でないと、表示すべき物体は透明の場合（図５（Ｅ）の場合）であるので、ステップ⑦に進む。

【００６１】一方、αが「０」（不透明）であると、表示すべき物体は不透明の場合（図５（Ｄ）の場合）であるので、他の物体はこれにより隠れるので、Ｚバッファ７、αバッファ９、不透明Ｚバッファ３、不透明画素値バッファ４のＸ、Ｙに対応する位置の内容を、それぞれ表示すべき物体のＺ値Ｚ、透明度α、Ｚ値Ｚ、画素値Ｄで更新して、ステップ①に戻る。

【００６２】⑦ステップ⑥で、αが「０」（不透明）でないと、表示すべき物体は透明の場合（図５（Ｅ）の場合）であるので、ステップ④の（３）式で復元画素値Ｄ１を計算する。表示すべき物体は透明の場合であるので、図５（Ｅ）に示すように、２つ透明物体が並ぶため、新画素値Ｄ"と統合透明度α"を計算する。

【００６３】先ず、復元画素値Ｄ１、αバッファ９のα'、表示すべき物体の画素値Ｄ、透明度αを用い、新画素値Ｄ"を次の（８）式で計算する。

【００６４】

【数８】

$$D''=D\times(1-\alpha)+D_1\times(1-\alpha')\times\alpha$$

【００６５】次に、αバッファ９のα'、表示すべき物体の透明度αを用い、統合透明度α"をステップ⑤の（６）式で計算する。

【００６６】更に、新画素値Ｄ"、統合透明度α"、不

透明画素値バッファ４の画素値Ｄｕを用い、新画素値Ｄ"をステップ⑤の（７）式で計算する。

【００６７】そして、Ｚバッファ７、αバッファ９、画素値バッファ８のＸ、Ｙに対応する位置の内容を、それぞれ表示すべき物体のＺ値Ｚ、統合透明度α"、新画素値Ｄ"で更新して、ステップ①に戻る。

【００６８】このようにして、物体が多重化しても、正しく透明物体を三次元表示できる。

【００６９】（ｂ）他の実施例の説明処理部をプロセッサとし、プログラムにより実施した例で示したが、ハードウェアによって実現してもよい。

【００７０】以上本発明を実施例により説明したが、本発明の主旨の範囲内で種々変形が可能であり、本発明の範囲からこれらを排除するものではない。

【００７１】

【発明の効果】以上説明したように、本発明によれば、次の効果を奏する。

【００７２】①不透明Ｚバッファと不透明画素値バッファを設け、表示しようとする物体が不透明Ｚバッファの最も近い不透明物体より遠い場合には、画素値算出の対象としないため、表示しようとする物体の画素値によって、透明物体の表示が誤ることを防止でき、正しく透明物体を三次元表示できる。

【００７３】②表示しようとする物体が不透明Ｚバッファの最も近い不透明物体より近い場合でＺバッファの最も近い物体より遠い場合には、画素値を復元し、アルファ・ブレンディングするので、他の物体による画素値によって、透明物体の表示が誤ることを防止でき、正しく透明物体を三次元表示できる。

【００７４】③しかも、アルファ・ブレンディング法の高速性を保つこともできる。

【図面の簡単な説明】

【図１】本発明の原理図である。

【図２】本発明の一実施例構成図である。

【図３】本発明の一実施例三次元処理フロー図である。

【図４】本発明の一実施例三次元処理フロー図である。

【図５】本発明の一実施例の説明図である。

【図６】本発明の一実施例の不透明物体の後に挿入される場合の説明図である。

【図７】本発明の一実施例の透明物体と不透明物体の間に挿入される場合の説明図である。

【図８】Ｚバッファ法の説明図である。

【図９】従来技術の説明図である。

【図１０】従来のアルファ・ブレンディング法の説明図である。

【図１１】従来のアルファ・ブレンディング法の説明図である。

【図１２】従来技術の問題点説明図である。

【図１３】従来技術の問題点説明図である。

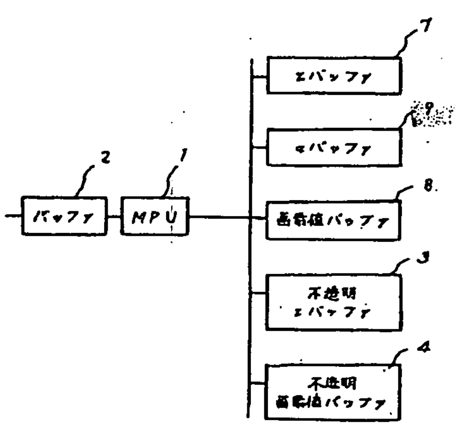
【図１４】従来技術の問題点説明図である。

【符号の説明】

１　処理部（プロセッサ）
３　不透明Ｚバッファ
４　不透明画元値バッファ
７　Ｚバッファ
８　画素値バッファ
９　αバッファ

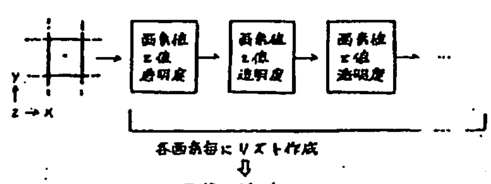
【図２】

一実施例構成図



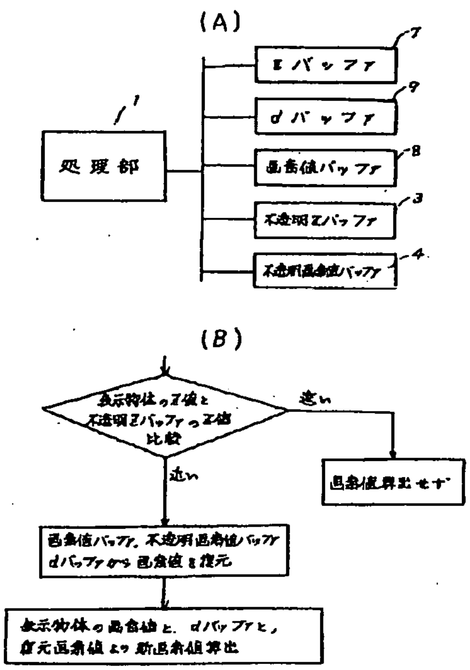
【図９】

従来技術の説明図



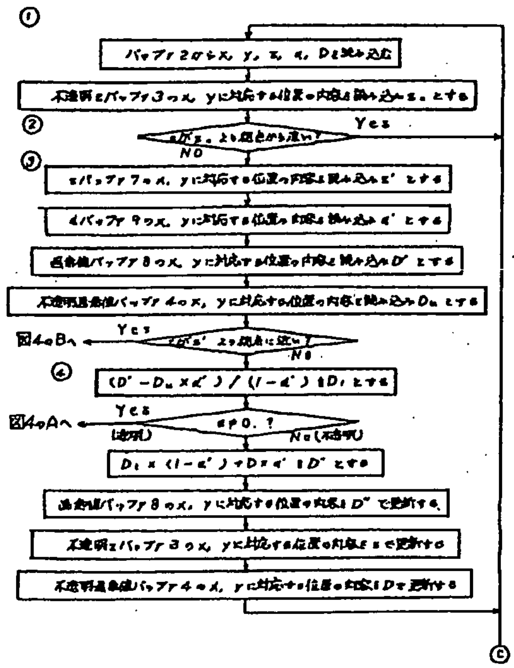
【図1】

本発明の原理図



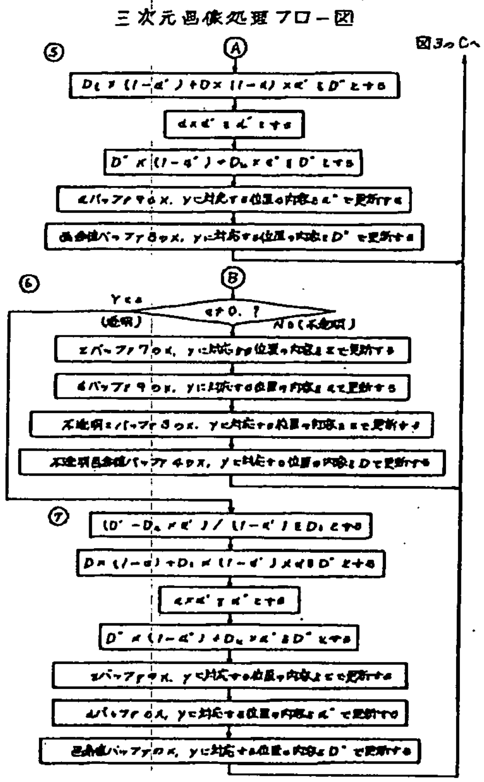
【図3】

三次元画像処理フロー図



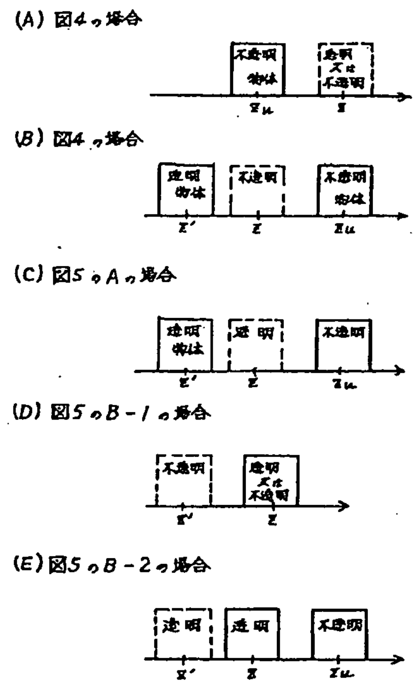
【図4】

三次元画像処理フロー図

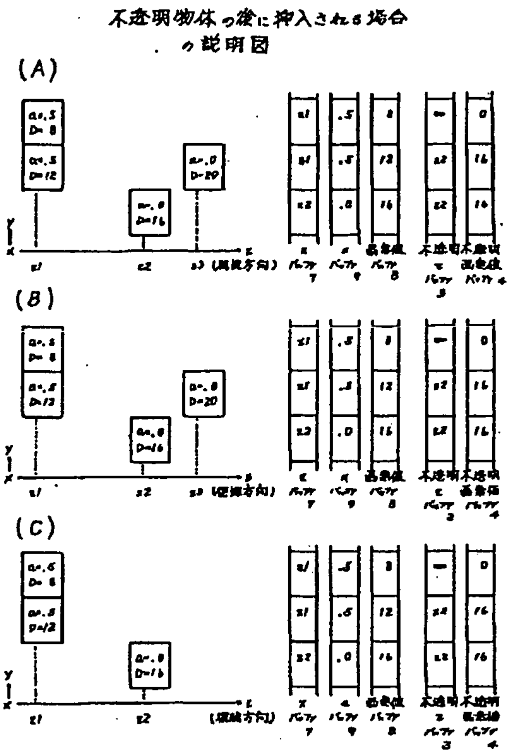


【図5】

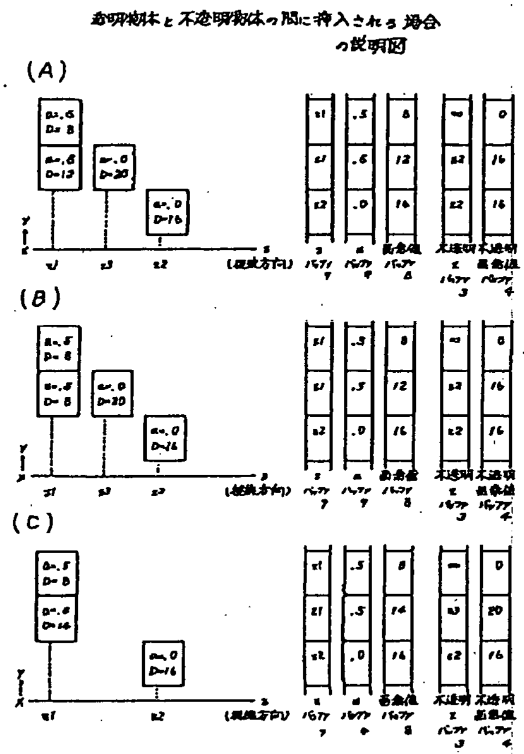
一実施例の説明図



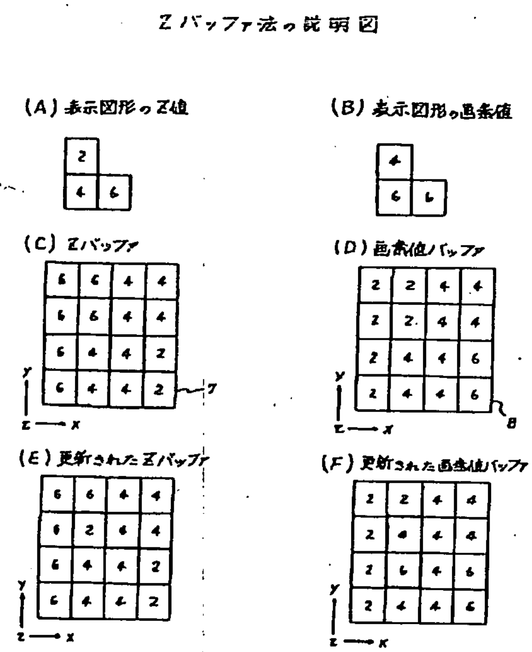
【図6】



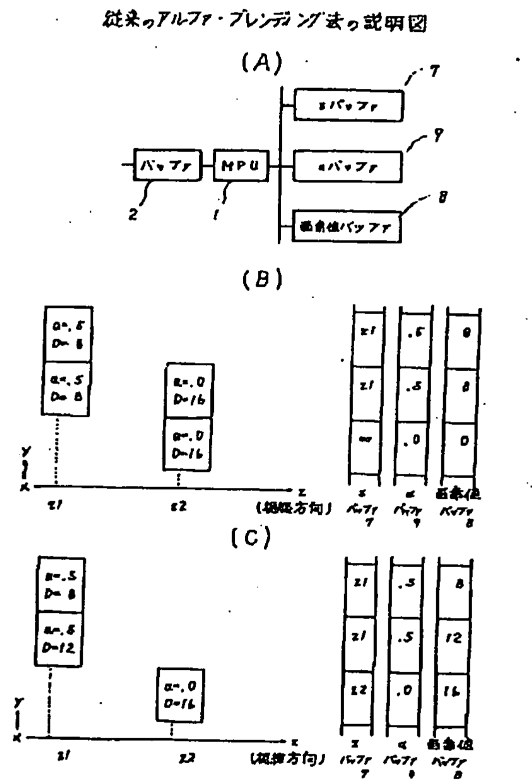
【図7】



【図8】

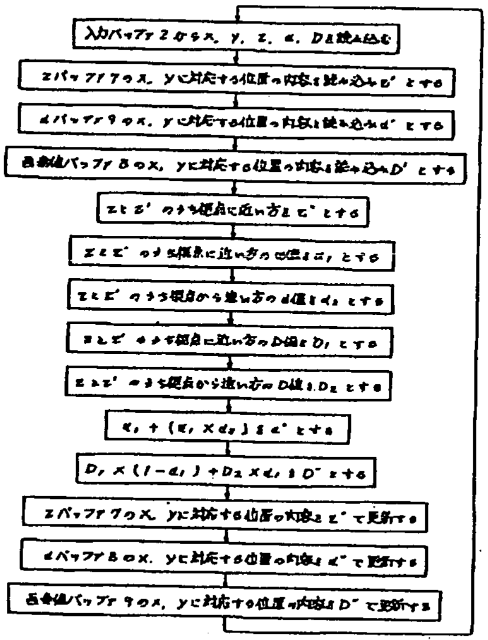

Zバッファ法の説明図
(A) 表示図形のZ値
(B) 表示図形の画素値
(C) Zバッファ
(D) 画素値バッファ
(E) 更新されたZバッファ
(F) 更新された画素値バッファ

【図10】


従来のアルファ・ブレンディング法の説明図
(A)
バッファ
MPU
zバッファ
αバッファ
画素値バッファ
(B)
(C)
(視線方向)

【図11】

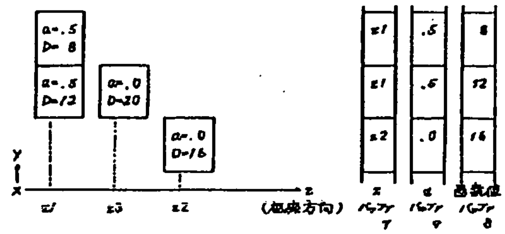
従来のアルファ・ブレンディング法の説明図



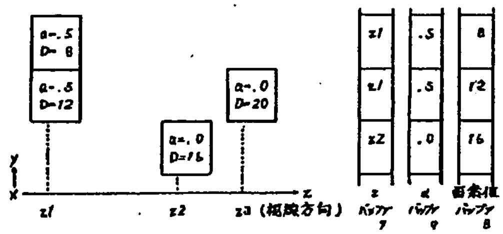
【図12】

従来技術の問題点説明図

（A）Z1とZ2の物体間に物体が挿入された場合



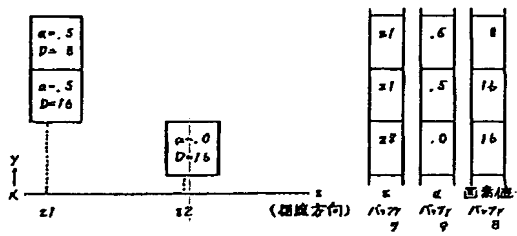
（B）Z2の後に物体が置かれた場合



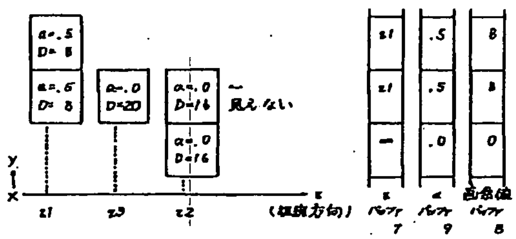
【図13】

従来技術の問題点説明図

（A）図12(A)(B)のブレンディング処理結果



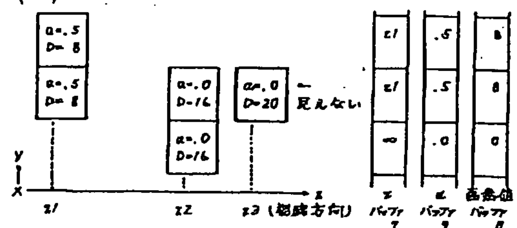
（B）図12(A)の本来の状態



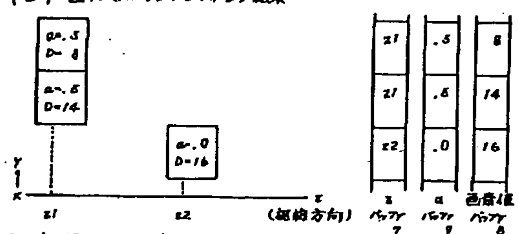
【図14】

従来技術の問題点説明図

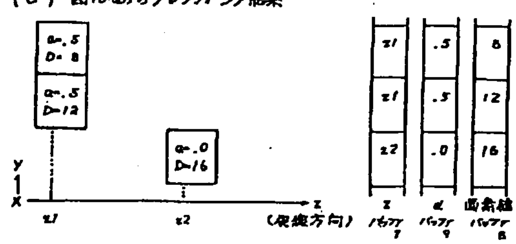
（A）図12(B)の本来の状態



（B）図13(A)のブレンディング結果



（C）図13(B)のブレンディング結果



PTO 03-4096

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THREE-DIMENSIONAL IMAGE DISPLAY PROCESSING METHOD
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Hiromichi Iwase and Hiroshi Nakayama

UNITED STATES PATENT AND TRADEMARK OFFICE
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(54) Title of the invention

Three-dimensional image display processing method

(57) Summary

Objective: It concerns a three-dimensional image display processing method wherein a transparent object is displayed based on the alpha blending method, and its objective is to accurately display a transparent object even in a case where multiple objects overlap.

Constitution: In a three-dimensional image display processing method for displaying a transparent object based on the alpha blending method, the intransparent Z buffer (3), in which the Z value of an intransparent object with the highest proximity is stored, and the intransparent pixel value buffer (4), in which the pixel value of said intransparent object with the highest proximity is stored, are configured, whereas the Z value of an object scheduled to be displayed and the Z value of the intransparent Z buffer (3) are compared, and in a case where the object scheduled to be displayed is farther than the intransparent object with the highest proximity, the pixel value of the object scheduled to be displayed is not targeted for pixel value calculation, whereas in a case where the object scheduled to be displayed is closer than the intransparent object with the highest proximity and where said object scheduled to be displayed is faster [sic: Presumably "farther"] than the intransparent object with the highest proximity for the Z buffer (7), the pixel value is restored from the pixel value of the pixel value buffer (8), the pixel value of the intransparent pixel value buffer (4), and the degree of transparency of the α buffer (9), whereas the new pixel value is calculated based on the pixel value of the object scheduled to be displayed, the degree of transparency of the α buffer (9), and the restored pixel value.

[1] Numbers in the margin indicate pagination in the foreign text.

Patent Claims /2

Claim 1

A three-dimensional image display processing method with the following characteristics: In an image processing device which possesses the Z buffer (7), in which the Z value, namely the depthwise position of an object with the highest proximity from the perspective of each member of the constituent pixels, is stored, the α buffer (9), in which the transparency of said object with the highest proximity specific to each of said pixels is stored, the pixel value buffer (8), in which the pixel value of each pixel is stored, and the processing unit (1) and wherein a transparent object is displayed by executing hidden plane eradication based on the comparison of the Z value of the object scheduled to be displayed and the Z value of said Z buffer (7) and by concomitantly calculating the new pixel value based on the transparency of said α buffer (9) and the pixel value of said object scheduled to be displayed,

The intransparent Z buffer (3), in which the Z value of said intransparent object with the highest proximity is stored, and the intransparent pixel value buffer (4), in which the pixel value of said intransparent object with the highest proximity is stored, are configured, whereas the Z value of the object scheduled to be displayed and the Z value of the intransparent Z buffer (3) are compared, and in a case where said object scheduled to be displayed is farther than said intransparent object with the highest proximity, the pixel value of said object scheduled to be displayed is not targeted for pixel value calculation, whereas in a case where said object scheduled to be displayed is closer than said intransparent object with the highest proximity and where said object scheduled to be displayed is farther than the intransparent object with the highest proximity for the Z buffer (7), said pixel value is restored from the pixel value of the pixel value buffer (8), the pixel value of the intransparent pixel value buffer (4), and the degree of transparency of the α buffer (9), whereas the new pixel value is calculated based on the pixel value of said object scheduled to be displayed, the degree of transparency of said α buffer (9), and said restored pixel value.

Claim 2

A three-dimensional image display processing method specified in Claim 1 characterized by the facts that, in a case where the aforementioned object scheduled to be displayed is a transparent object, the new pixel value is calculated based on the pixel value and the degree of transparency of the aforementioned object scheduled to be displayed and the aforementioned restored pixel value, that the new degree of transparency is calculated based on the degree of transparency of the aforementioned object scheduled to be displayed and the degree of transparency of the aforementioned α buffer (9), and that the new pixel value is calculated based on the aforementioned new pixel value, the aforementioned new degree of transparency, and the pixel value of the aforementioned intransparent pixel value buffer (4).

Claim 3

A three-dimensional image display processing method specified in Claim 1 characterized by the facts that, in a case where the aforementioned object scheduled to be displayed is closer than the aforementioned intransparent object with the highest proximity, where the aforementioned object scheduled to be displayed is closer than the aforementioned intransparent object with the highest proximity for said Z buffer (7), and where the aforementioned object scheduled to be displayed is a transparent object, the aforementioned pixel value is restored based on the pixel value of the aforementioned pixel value buffer (8), the pixel value of the aforementioned intransparent pixel value buffer (4), and the degree of transparency of the aforementioned α buffer (9), that the new pixel value is calculated based on the pixel value and degree of transparency of the aforementioned object scheduled to be displayed, the degree of transparency of the aforementioned α buffer (9), and the aforementioned restored pixel value, and that the new pixel value is calculated based on the aforementioned new pixel value, the aforementioned new degree of transparency, and the pixel value of the aforementioned intransparent pixel value buffer (4).

Detailed explanation of the invention

[0001]

INDEX

Industrial application fields (Figure 8)

Prior art (Figures 9 through 11)

Problems to be solved by the invention (Figures 12 through 14)

Mechanism for solving the problems (Figure 1)

Function

Application examples

(a): Explanation of one application example (Figures 12 through [1]7)

(b): Explanation of another application example

Effects of the invention

[0002]

(Industrial application fields)

The present invention concerns a three-dimensional image display processing method for displaying a transparent object based on the alpha blending method.

[0003]

High-speed computerized displays of three-dimensional images have become possible thanks to the hardware sophistications of recent years. The Z buffer method is known as a fundamental technology in this context. The Z buffer method is one known method for eradicating a hidden plane that arises as a result of an overlap of objects in a case where an object configured within a three-dimensional space is viewed from a certain perspective, and in particular, it is an indispensable technique for the high-speed display of a three-dimensional image.

[0004]

Figure 8 is a demonstrational diagram pertaining to the Z buffer method.

[0005]

As Figures 8 (C) and (D) show, the Z buffer method utilizes the Z buffer (7), in which the Z value, namely the depthwise position of a pattern with the highest proximity from the perspective of each member of the respective pixels of a screen, is stored, and the pixel value buffer (8), in which the pixel value of said pattern is stored.

[0006]

As Figure 8 (A) shows, furthermore, the Z value of each pixel of a pattern scheduled to be displayed (a triangle is hereby instantiated) (depthwise position from its perspective) [is calculated], and as Figure 8 (A) indicates, the pixel value of each pixel of said pattern is calculated, whereas, in a case where its Z value is closer to the perspective than the Z value of the corresponding pixel of the Z buffer (7), the contents of the corresponding pixels of the pixel value buffer (8) and Z buffer (7) are substituted, as Figures 8 (E) and (F) indicate, with the Z values and pixel values of the pixels of the pattern scheduled to be displayed [bold lined portions of Figures 8 (E) and (F)], whereas in a case where the same is farther, no substitutions of the Z value and pixel value are executed; thus, only a surface or portion of the surface visible from said perspective is eventually displayed.

[0007]

This Z buffer method is flawed in that it is incapable of displaying a transparent object, for it is simply designed to assume objects to be intransparent and to judge their forward and/or backward statuses.

[0008]

It is for this reason that the development of a three-dimensional image display processing technique which is capable of three-dimensionally displaying transparent objects as well has become urgent.

[0009]

(Prior art)

Figure 9 is a demonstrational diagram pertaining to the prior art.

[0010]

One modality for displaying a transparent object is the method shown in Figure 9, wherein pixel information data corresponding to an object scheduled to be displayed (i.e., pixel value, Z value, and degree of transparency) specific to the respective pixels of the pixel value buffer (8) are saved as a list in the order of appearance, wherein, upon the collection of information on all objects, [said list is] sorted in terms of the Z value, and wherein the pixel value is ascertained, until the emergence of an intransparent object, in consideration of the degree of transparency. /3

[0011]

As far as this method is concerned, a three-dimensional image inclusive of a transparent object can be accurately displayed, but an immense memory is required for the preparation of the list, and since the list must be sorted, an immense computation burden becomes imposed, whereas another shortcoming lies in its hardware unfriendliness.

[0012]

In this context, the alpha blending method has been proposed as a method which yields a transparent appearance at a high speed, although it may not be capable of accurately displaying a three-dimensional image inclusive of a transparent object. In this method, the hidden plane eradication is executed by the Z buffer method, and an α buffer for storing the degree of transparency of an object is prepared in addition to a Z buffer; in the context of displaying a transparent object, transparent object pixel values proportional to the degree of transparency of said object are added to the pixel values of the corresponding pixels which have already been stored in the pixel value buffer (8).

[0013]

Figures 10 and 11 are demonstrational diagrams pertaining to the alpha blending method of the prior art.

[0014]

As Figure 10 (A) shows, the α buffer (9) is configured in addition to the Z buffer (7) and pixel value buffer (8), and display data inputted into the input buffer (2) are subjected to an alpha blending routine executed by the processor (MPU) (1).

[0015]

As Figure 10 (B) shows, a case where an intransparent object with a Z value of Z2 (degree of transparency of a = 0.0; pixel value D = 16) is displayed while a transparent object with a Z value of Z1 (degree of transparency a = 0.5; pixel value D = 8) is being concomitantly displayed may, for example, be considered.

[0016]

The respective contents of the Z buffer (7), α buffer (9), and the pixel value buffer (8) in this case indicate the pervasion of a transparent object the Z value of which is Z1, as Figure 10 (B) shows. One pixel of the intransparent object the Z value of which is Z2 overlaps said transparent object the Z value of which is Z1, whereas the post-blend pixel value Db is calculated by using the following formula (1):

[0017]

[Numerical 1]: Db = Dt x (1 - at) + Di x at.

[0018]

In the above, "Dt" signifies the pixel value of the transparent object, whereas "at" signifies the degree of transparency of the transparent object, whereas "Di" signifies the pixel value of the intransparent object.

[0019]

The pixel value of the transparent object and the pixel value of the intransparent object can respectively be displayed as they are in areas over which the transparent object and intransparent object do not overlap, and therefore, the respective contents of the Z buffer (7), α buffer (9), and the

pixel value buffer (8) become permutated to those shown in Figure 10 (C) as a result of the alpha blending routine.

[0020]

The corresponding processing flow is shown in Figure 11.

[0021]

Pixel information data (X, Y, Z, α, and D) on a pattern scheduled to be displayed are encoded from the input buffer (2), and the contents of the positions corresponding respectively to X and Y of the Z buffer (7), α buffer (9), and the pixel value buffer (8) are encoded and parameterized respectively as Z', α', and D'. The processor (1) compares Z and Z', defines the Z value of either member selected from between Z and Z' closer to the perspective as Z", the α value as $\alpha 1$, and the D value as D1, whereas it defines the α value of the other member of Z and Z', which is farther from the perspective, as $\alpha 2$ and its D value as D2. The renewed degree of transparency α" is then calculated by using the following formula (2):

[0022]

[Numerical 2]: $\alpha'' = \alpha 1 + (\alpha 1 \times \alpha 2)$.

[0023]

Next, D1, $\alpha 1$, and D2 are substituted respectively into Dt, at, and Di in the aforementioned formula (1), as a result of which D" becomes obtained. The contents of the positions corresponding respectively to X and Y of the Z buffer (7), α buffer (9), and the pixel value buffer (8) are then renewed respectively with Z", α", and D".

[0024]

It is thus that an intransparent object can be three-dimensionally displayed via a transparent object (e.g., glass, etc.).

[0025]

(Problems to be solved by the invention)

Figures 12, 13, and 14 are demonstrational diagrams provided for articulating the problems of the alpha blending technique of the prior art.

[0026]

In a case where, upon the completion of the blending routine of Figure 10 (C), an intransparent object the Z value of which is Z3 becomes inserted, as Figure 12 (A) shows, between a transparent object the Z value of which is Z1 and an intransparent object the Z value of which is Z2, [the inserted object] may become configured behind the intransparent object the Z value of which is Z2, as Figure 12 (B) indicates. In a case where the alpha blending method of the prior art shown in Figure 11 is applied to such an embodiment, the blending routine is executed based on the respective contents of the Z buffer (7), α buffer (9), and the pixel value buffer (8) and the contents of the pixel information on the intransparent object the Z value of which is Z3, and as Figure 13 (A) indicates, the post-blend pixel value comes to reflect all the corresponding pixel values of the objects the respective Z values of which are Z1, Z2, and Z3.

[0027]

Incidentally, as far as the original state of Figure 12 (A) is concerned, the intransparent object the Z value of which is Z2 is hidden from view by the intransparent object the Z value of which is Z3, as Figure 13 (B) indicates, and thus, as Figure 14 (A) shows, the original state of Figure 12 (A) is a state where the intransparent object the Z value of which is Z2 is hidden from view by the intransparent object the Z value of which is Z3.

[0028]

In Figure 12 (A), therefore, the correct display results should be determined from the respective pixel values of the transparent object the Z value of which is Z1 and the intransparent object the Z value of which is Z3 according to the protocol of Figure 14 (B), whereas in Figure 12 (B), the same should be determined from the respective pixel values of the transparent object the Z value of which is Z1 and the intransparent object the Z value of which is Z2 according to the protocol of Figure 14 (C).

[0029]

Thus, the high speed is emphasized, in acknowledgment of hardware friendliness, in the alpha blending method of the prior art, and the pervasion of a singular object is assumed during its routine regardless of the order of prevailing objects, which is problematic in that a transparent object cannot be accurately displayed in a case where multiple objects overlap.

[0030]

The objective of the present invention is therefore to provide a three-dimensional image display processing method for displaying a transparent object based on the alpha blending method, and its objective is to accurately display a transparent object even in a case where multiple objects overlap. /4

[0031]

(Mechanism for solving the problems)

Figure 1 is a principle diagram pertaining to the present invention.

[0032]

The constitution of Claim 1 of the present invention is characterized as follows: In an image processing device which possesses the Z buffer (7), in which the Z value, namely the depthwise position of an object with the highest proximity from the perspective of each member of the constituent pixels, is stored, the α buffer (9), in which the transparency of said object with the highest proximity specific to each of said pixels is stored, the pixel value buffer (8), in which the pixel value of each pixel is stored, and the processing unit (1) and wherein a transparent object is displayed by executing hidden plane eradication based on the comparison of the Z value of the object scheduled to be displayed and the Z value of said Z buffer (7) and by concomitantly calculating the new pixel value based on the transparency of said α buffer (9) and the pixel value of said object scheduled to be displayed, the intransparent Z buffer (3), in which the Z value of said intransparent object with the highest proximity is stored, and the intransparent pixel value buffer (4),

in which the pixel value of said intransparent object with the highest proximity is stored, are configured, whereas the Z value of the object scheduled to be displayed and the Z value of the intransparent Z buffer (3) are compared, and in a case where said object scheduled to be displayed is farther than said intransparent object with the highest proximity, the pixel value of said object scheduled to be displayed is not targeted for pixel value calculation, whereas in a case where said object scheduled to be displayed is closer than said intransparent object with the highest proximity and where said object scheduled to be displayed is farther than the intransparent object with the highest proximity for the Z buffer (7), said pixel value is restored from the pixel value of the pixel value buffer (8), the pixel value of the intransparent pixel value buffer (4), and the degree of transparency of the α buffer (9), whereas the new pixel value is calculated based on the pixel value of said object scheduled to be displayed, the degree of transparency of said α buffer (9), and said restored pixel value.

[0033]

The constitution of Claim 2 of the present invention is a constitution specified in Claim 1 characterized by the facts that, in a case where the aforementioned object scheduled to be displayed is a transparent object, the new pixel value is calculated based on the pixel value and the degree of transparency of the aforementioned object scheduled to be displayed and the aforementioned restored pixel value, that the new degree of transparency is calculated based on the degree of transparency of the aforementioned object scheduled to be displayed and the degree of transparency of the aforementioned α buffer (9), and that the new pixel value is calculated based on the aforementioned new pixel value, the aforementioned new degree of transparency, and the pixel value of the aforementioned intransparent pixel value buffer (4).

[0034]

The constitution of Claim 3 of the present invention is a constitution specified in Claim 1 characterized by the facts that, in a case where the aforementioned object scheduled to be displayed is closer than the aforementioned intransparent object with the highest proximity, where the

aforementioned object scheduled to be displayed is closer than the aforementioned intransparent object with the highest proximity for said Z buffer (7), and where the aforementioned object scheduled to be displayed is a transparent object, the aforementioned pixel value is restored based on the pixel value of the aforementioned pixel value buffer (8), the pixel value of the aforementioned intransparent pixel value buffer (4), and the degree of transparency of the aforementioned α buffer (9), that the new pixel value is calculated based on the pixel value and degree of transparency of the aforementioned object scheduled to be displayed, the degree of transparency of the aforementioned α buffer (9), and the aforementioned restored pixel value, and that the new pixel value is calculated based on the aforementioned new pixel value, the aforementioned new degree of transparency, and the pixel value of the aforementioned intransparent pixel value buffer (4).

[0035]

(Functions)

In a case where an overlap of a transparent object and an intransparent object is observed, once an intransparent object appears, all objects positioned behind it become utterly invisible from the prevailing perspective. In other words, only the information on an intransparent object closest to the perspective is needed for the image scheduled to be displayed. In Claim 1 of the present invention, therefore, the intransparent Z buffer (3), in which the Z value of an intransparent object with the highest proximity is stored, and the intransparent pixel value buffer (4), in which the pixel value of said intransparent object with the highest proximity is stored, are configured.

[0036]

In a case where an intransparent object displayed later is farther from the perspective than the previously displayed intransparent object, therefore, a transparent object can be accurately displayed so long as the pixel value of the subsequently displayed intransparent object is not blended. In this context, the Z value of the object scheduled to be displayed and the Z value of the

intransparent Z buffer (3) are compared, and in a case where the object scheduled to be displayed is farther than the intransparent object with the highest proximity, the pixel value of the object scheduled to be displayed is not targeted for pixel value calculation.

[0037]

In a case where the intransparent object displayed later is closer to the perspective than the previously displayed intransparent object, on the other hand, a transparent object can be accurately displayed so long as the blended pixel value can be re-calculated. In a case where the object scheduled to be displayed is closer than the intransparent object with the highest proximity and where said object scheduled to be displayed is farther than the object of the Z buffer (7) with the highest proximity, therefore, the pixel value is restored from the pixel value of the pixel value buffer (8), the pixel value of the intransparent pixel value buffer (4), and the degree of transparency of the α buffer (9), whereas the new pixel value is designed to be calculated based on the pixel value of the object scheduled to be displayed, the degree of transparency of the α buffer (9), and the restored pixel value.

[0038]

Even in a case where the object scheduled to be displayed is a transparent object, overlapping transparent objects can be displayed while the degree of transparency of said transparent object is being taken into consideration according to Claim 2 of the present invention.

[0039]

Even in a case where the object scheduled to be displayed is a transparent object and is the closest to the perspective, overlapping transparent objects can be displayed while the degree of transparency of said transparent object is being taken into consideration according to Claim 2 of the present invention.

[0040]

(Application examples)

(a): <u>Explanation of one application example</u>

Figure 2 is a constitutional diagram pertaining to an application example of the present invention, and in said figure, members identical to those shown in Figures 1 and 10 are designated to bear identical notations.

[0041]

In Figure 2, the Z buffer (7), the α buffer (9), the pixel value buffer (8), the intransparent Z buffer (3), and the intransparent pixel value buffer (4) are constituted by a singular memory.

[0042]

Figures 3 and 4 are each three-dimensional image processing flow charts of [said] application example of the present invention, whereas Figure 5 is a demonstrational diagram pertaining to [said] application example of the present invention, whereas Figure 6 is a demonstrational diagram of a case where an inserted member exists behind an intransparent object, whereas Figure 7 is a demonstrational diagram of a case where an inserted member exists between a transparent object and an intransparent object.

[0043]

<1>: The processor (1) encodes, from the input buffer (2), pixel information data on an object scheduled to be displayed (X, Y, Z, α, and D) and further encodes the contents of the positions corresponding respectively to X and Y of the intransparent Z buffer (3) and defines them as Zu. /5

[0044]

<2>: The processor (1) compares Z and Zu. In a case where $Z > Zu$ holds, the object scheduled to be displayed is located behind the intransparent object (i.e., farther) and is hidden by said intransparent object, as Figure 5 (A) and Figure 6 indicate, and therefore, a return to the step <1> is made without renewing the respective contents of all buffers (3), (4), (7), (8), and (9), as Figure 6 indicates.

[0045]

<3>: In a case where the object scheduled to be displayed is not located behind the intransparent object (i.e., farther), the processor (1) encodes the contents of the positions corresponding respectively to X and Y of the Z buffer (7), the α buffer (9), the pixel value buffer (8), and the intransparent pixel value buffer (4) and defines them as Z', α', D', and Du, respectively. The processor (1) also compares Z and Z'. In a case where $Z > Z'$ holds, the object scheduled to be displayed exists between a transparent object and an intransparent object, as Figures 5 (B) and (C) indicate, and an advancement to the step <4> is made, whereas in a case where $Z < Z'$ holds, the object scheduled to be displayed exists in front of a transparent object, as Figures 5 (D) and (E) indicate, and an advancement to the step <6> (B in Figure 4) is made.

[0046]

<4>: In a case where the object scheduled to be displayed exists between the transparent object and intransparent object, the pixel value is initially restored. The restored pixel value D1 is calculated from the D' of the pixel value buffer (8), Du of the intransparent pixel value buffer (4), and α' of the α buffer (9) by using the following formula (3):

[0047]

[Numerical 3]: $D1 = (D' - Du \times \alpha')/(1 - \alpha')$.

[0048]

Next, the processor (1) judges whether or not the degree of transparency α of the object scheduled to be displayed is "0" (intransparent). In a case where α is not "0" (intransparent), a state where the object scheduled to be displayed is transparent [case of Figure 5 (C)] is judged, and accordingly, an advancement to the step <5> (A in Figure 4) is made.

[0049]

In a case where α is "0" (intransparent), on the other hand, a state where the object scheduled to be displayed is intransparent [case of Figure 5 (B)] is judged, and accordingly, the new pixel value D" is calculated from the restored pixel value D1, α' of the α buffer (9), and the pixel

value D of the object scheduled to be displayed by using the following formula (4), as Figure 7 shows:

[0050]

[Numerical 4]: $D'' = D1 \times (1 - \alpha') + D \times \alpha'$.

[0051]

This formula is identical to the formula (1). Next, the contents of the positions corresponding respectively to X and Y of the pixel value buffer (8), intransparent Z buffer (3), and the intransparent pixel value buffer (4) are renewed respectively with the new pixel value D", Z, and D, and a return to the step <1> is made.

[0052]

<5>: In a case where α is not "0" (intransparent), the object scheduled to be displayed is judged to be transparent, and since a pair of transparent objects coexist, as Figure 5 (C) shows, the new pixel value D" and the unified degree of transparency α" are calculated.

[0053]

First, the new pixel value D" is calculated from the restored pixel value D1, α' of the α buffer (9), and the pixel value D and degree of transparency α of the object scheduled to be displayed by using the following formula (5):

[0054]

[Numerical 5]: $D'' = D1 \times (1 - \alpha') + D \times (1 - \alpha) \times \alpha'$.

[0055]

Next, the unified degree of transparency α" is calculated from the α' of the α buffer (9) and the degree of transparency α of the object scheduled to be displayed by using the following formula (6):

[0056]

[Numerical 6]: $\alpha'' = \alpha \times \alpha'$.

[0057]

The new pixel value D", furthermore, is calculated from the new pixel value D", unified degree of transparency α'', and the pixel value Du of the intransparent pixel value buffer (4) by using the following formula (7):

[0058]

[Numerical 7]: $D'' = D'' \times (1 - \alpha'') + Du \times \alpha''$.

[0059]

The contents of the positions corresponding respectively to X and Y of the α buffer (9) and pixel value buffer (8), furthermore, are renewed respectively with the unified degree of transparency α'' and the new pixel value D", and a return to the step <1> is made.

[0060]

<6>: In a case where the object scheduled to be displayed is judged to exist in front of a transparent object at the step <3>, the processor (1) judges whether or not the degree of transparency α of the object scheduled to be displayed is "0" (intransparent). In a case where α is not "0" (intransparent), the object scheduled to be displayed is judged to be transparent [case of Figure 5 (E)], and accordingly, an advancement to the step <7> is made.

[0061]

In a case where α is "0" (intransparent), on the other hand, the object scheduled to be displayed is judged to be intransparent [case of Figure 5 (D)], and accordingly, the contents of the positions corresponding respectively to the X and Y of the Z buffer (7), the α buffer (9), the intransparent Z buffer (3), and the intransparent pixel value buffer (4) are renewed respectively with the Z value Z, degree of transparency α, Z value Z, and the pixel value D of the object scheduled to be displayed, and a return to the step <1> is then made.

[0062]

<7>: In a case where α is not "0" (intransparent) at the step <6>, the object scheduled to be displayed is judged to be transparent [case of Figure 5 (E)], and accordingly, the restored pixel value D1 is calculated by using the formula (3) of the step <4>. Since the object scheduled to be

displayed has been judged to be transparent, a pair of transparent objects coexist, as Figure 5 (E) indicates, and the new pixel value D" and unified degree of transparency α" are then calculated.

[0063]

First, the new pixel value D" is calculated from the restored pixel value D1, α' of the α buffer (9), and the pixel value D and degree of transparency α of the object scheduled to be displayed by using the following formula (8):

[0064]

[Numerical 8]: $D'' = D \times (1 - \alpha) + D1 \times (1 - \alpha') \times \alpha$.

[0065]

Next, the unified degree of transparency α" is calculated from the α' of the α buffer (9) and the degree of transparency α of the object scheduled to be displayed by using the formula (6) of the step <5>.

[0066]

Moreover, the new pixel value D" is calculated from the new pixel value D", unified degree of transparency α", and the pixel value Du of the intransparent pixel value buffer (4) by using the /6 formula (7) of the step (5).

[0067]

The contents of the positions corresponding respectively to X and Y of the Z buffer (7), α buffer (9), and after the pixel value buffer (8) have been renewed respectively with the Z value Z, unified degree of transparency α", and new pixel value D" of the object scheduled to be displayed, a return to the step <1> is made.

[0068]

It is thus that a transparent object can be accurately displayed three-dimensionally even in a case where multiple objects overlap.

[0069]

(b): Explanation of another application example

A case where a processing unit is constituted by a processor and where it is embodied programwise has been instantiated above, although the same may instead be embodied hardwarewise.

[0070]

The present invention has, in the above, been explained with reference to application examples, although the present invention can be variously modified so long as its spirit is retained, and such modifications do not deviate from the scope of the present invention.

[0071]

(Effects of the invention)

As the foregoing explanations have demonstrated, the following effects can be achieved in the present invention.

[0072]

<1>: An intransparent Z buffer and an intransparent pixel value buffer are configured, and in a case where an object scheduled to be displayed is farther than the intransparent object of the intransparent Z buffer with the highest proximity, it is not targeted for pixel value calculation, based on which erroneous displays of transparent objects depending on the pixel value of the object scheduled to be displayed can be prevented, and the transparent object can be accurately displayed three-dimensionally.

[0073]

<2>: In a case where the object scheduled to be displayed is closer than the intransparent object of the intransparent Z buffer with the highest proximity and farther than the object of the Z buffer with the highest proximity, the pixel value is restored and then subjected to alpha blending, based on which erroneous displays of transparent objects depending on the pixel values of other

objects can be prevented, and the transparent object can be accurately displayed three-dimensionally.

[0074]

<3>: The high speed unique to the alpha blending method can, furthermore, be preserved.

Brief explanation of the figures

Figure 1: A principle diagram of the present invention.

Figure 2: A constitutional diagram pertaining to an application example of the present invention.

Figure 3: A three-dimensional processing flow chart pertaining to [said] application example of the present invention.

Figure 4: Another three-dimensional processing flow chart pertaining to [said] application example of the present invention.

Figure 5: A demonstrational diagram pertaining to [said] application example of the present invention.

Figure 6: A demonstrational diagram pertaining to a case where an inserted member exists behind an intransparent object in [said] application example of the present invention.

Figure 7: A demonstrational diagram pertaining to a case where an inserted member exists between a transparent object and an intransparent object in [said] application example of the present invention.

Figure 8: A demonstrational diagram pertaining to the Z buffer method.

Figure 9: A demonstrational diagram pertaining to the prior art.

Figure 10: A demonstrational diagram pertaining to the alpha blending method of the prior art.

Figure 11: Another demonstrational diagram pertaining to the alpha blending method of the prior art.

Figure 12: A demonstrational diagram provided for explaining the problems of the prior art.

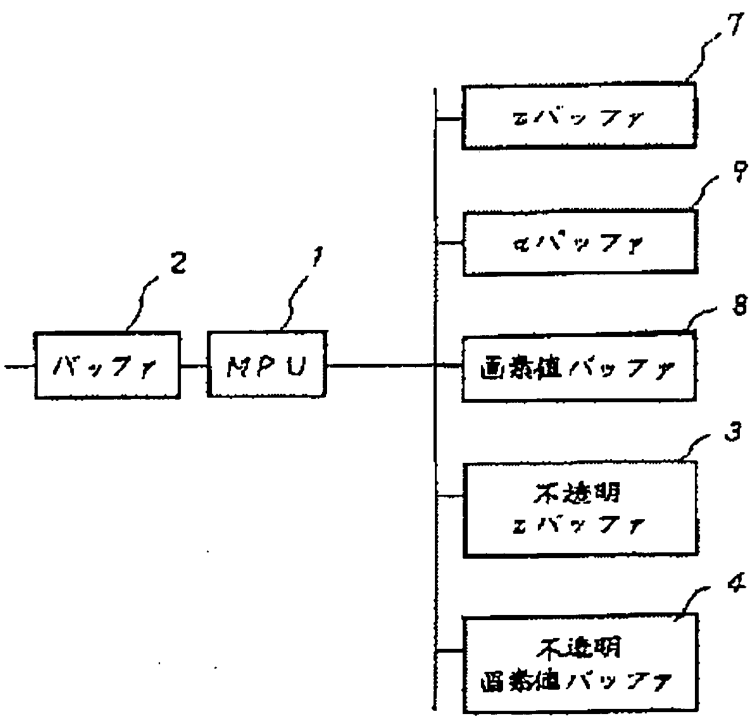
Figure 13: Another demonstrational diagram provided for explaining the problems of the prior art.

Figure 14: Still another demonstrational diagram provided for explaining the problems of the prior art.

(Explanation of notations)

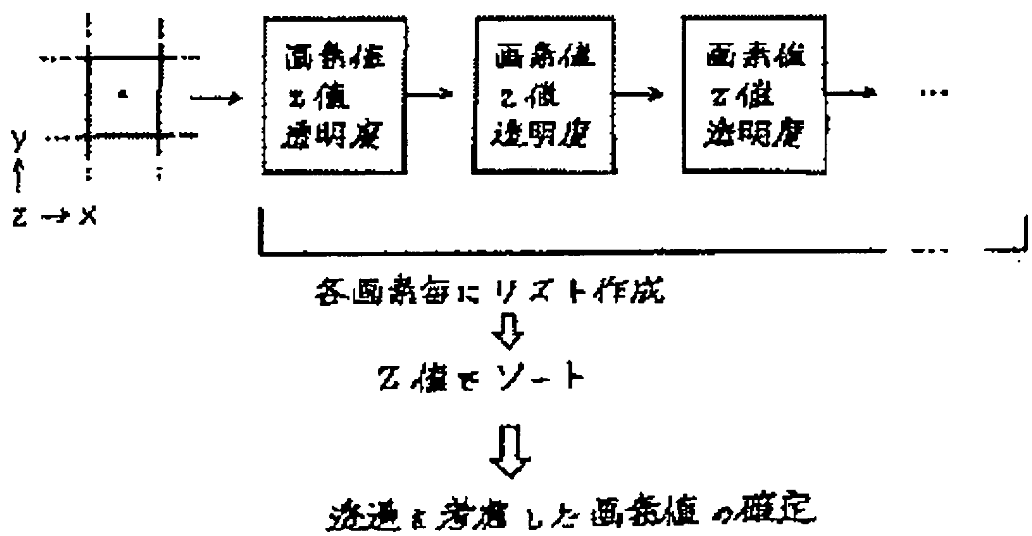
(1): Processing unit (processor); (3): Intransparent Z buffer; (4): Intransparent pixel value buffer; (7): Z buffer; (8): Pixel value buffer; (9): α buffer.

Figure 2



[(0): Constitutional diagram of an application example; (2): Buffer; (3): Intransparent Z buffer; (4): Intransparent pixel value buffer; (7): Z buffer; (8): Pixel value buffer; (9): α buffer]

Figure 9

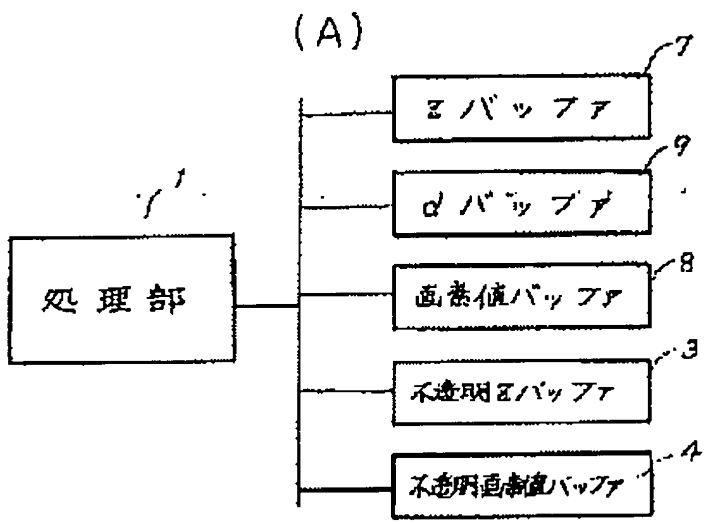


[(0): Demonstrational diagram of the prior art; (1): Pixel value, Z value, and degree of transparency; (2): Preparation of a list for each pixel; (3): Sorting by Z value; (4): Ascertainment of pixel value by taking the transparency into consideration]

(A)

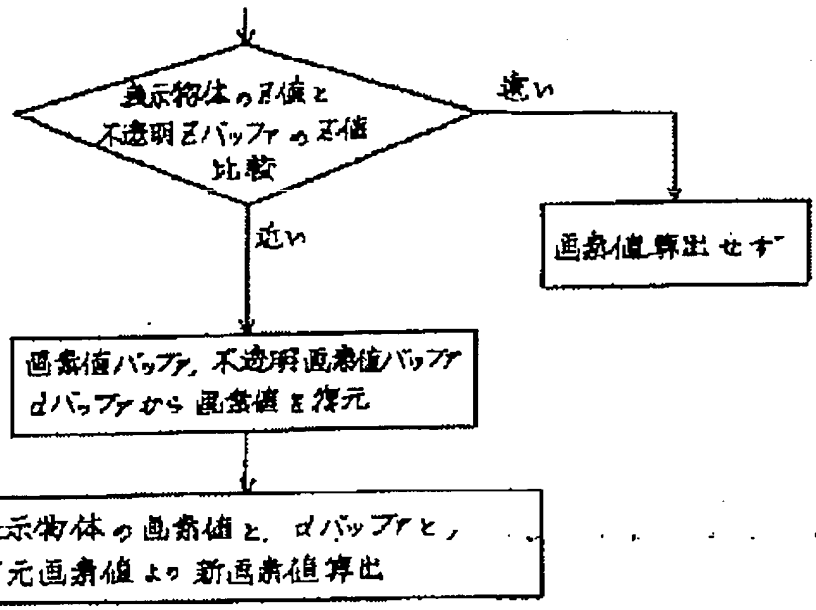
【図1】

本発明の原理図



(B)

(B)

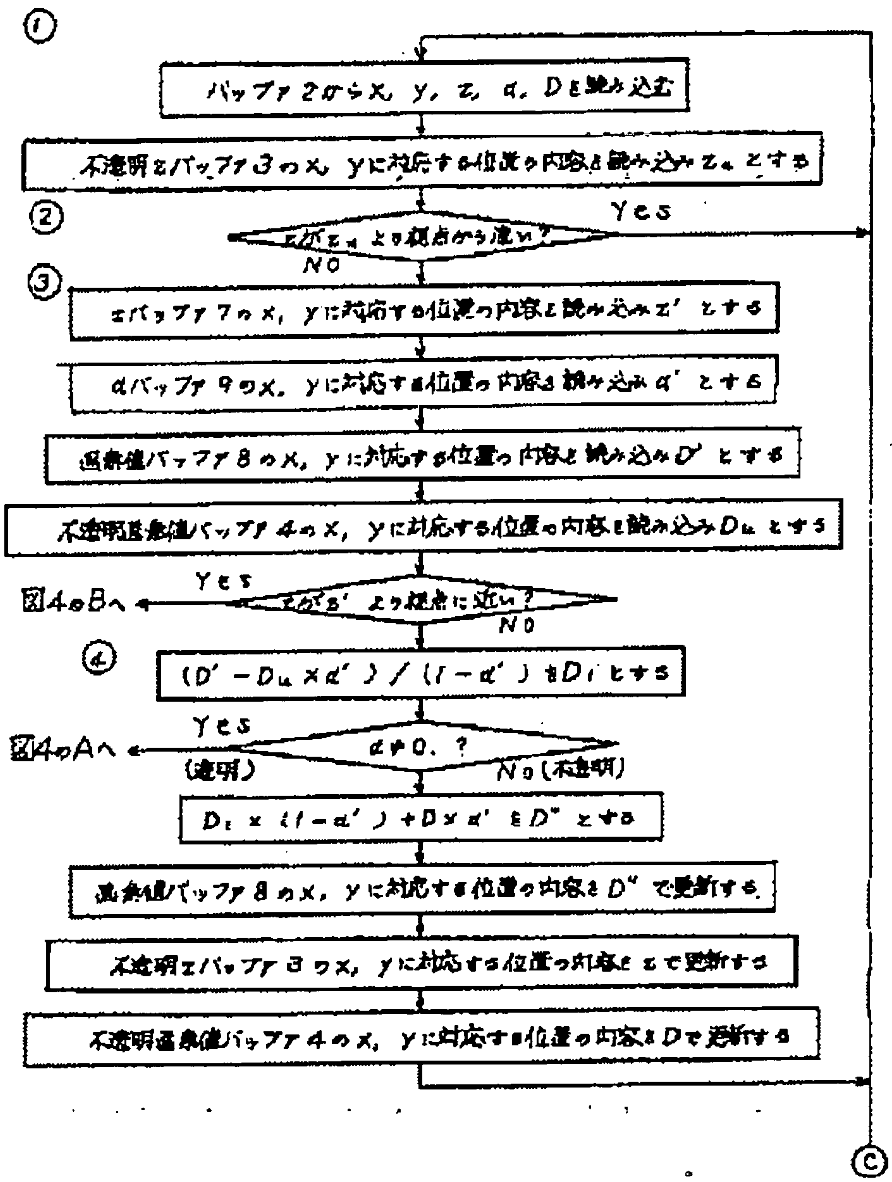


[(0): Principle diagram of the present invention; (1): Processing unit; (3): Intransparent Z buffer; (4): Intransparent pixel value buffer; (7): Z buffer; (8): Pixel value buffer; (9): α buffer; (i): Comparison of th e Z value of the object scheduled to be displayed and the Z value of of the intransparent Z buffer; (ii): Restoration of the pixel value from the pixel value buffer, intransparent pixel value buffer, and α buffer; (iii): Calculation of the new pixel value from the pixel value of the object scheduled to be displayed, [α value of] the α buffer, and the restored pixel value; (vi): No calculation of the pixel value; (v): Far; (vi): Close]

Figure 3

【図3】

三次元画像処理フロー図



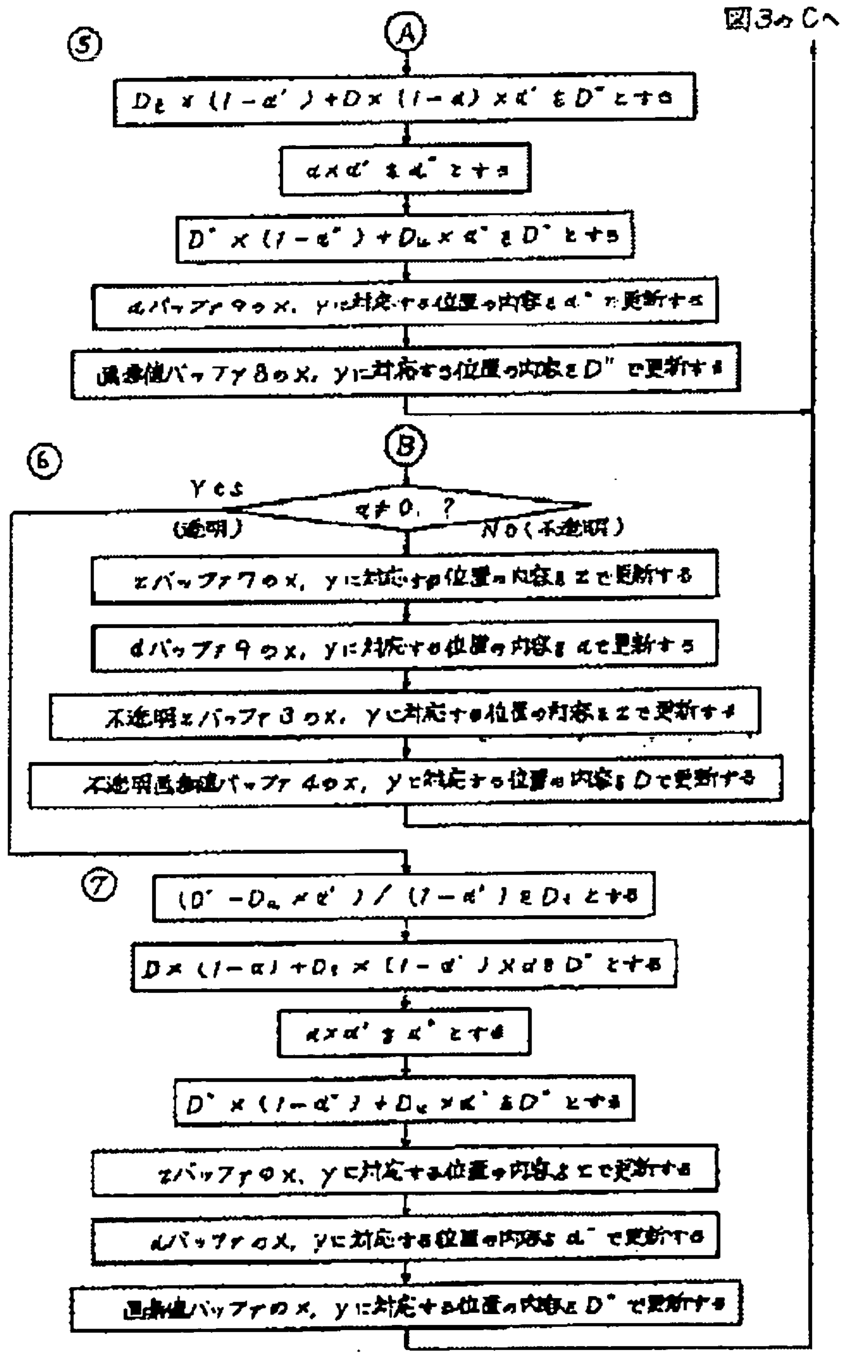
[(0): Three-dimensional image processing flow chart; (1): Encoding of X, Y, Z, α, and D1 from buffer 2; (2): Encoding of the contents of the positions corresponding respectively to X and Y of intransparent Z buffer 3 and defining them as Z[u]; (3): Is Z farther than Zu from perspective?; (4): Encoding of the contents of the positions corresponding respectively to X and Y of Z buffer 7 and defining them as Z'; (5): Encoding of the contents of the positions corresponding respectively to X and Y of α buffer 9 and defining them as α'; (6): Encoding of the contents of the positions corresponding respectively to X and Y of pixel value buffer 8 and defining them as D'; (7): Encoding of the contents of the positions corresponding respectively to X and Y of Z intransparent pixel value buffer 4 and defining them as D[u]; (8): Is Z closer to perspective than Z'?; (9): To B in Figure 4; (10): (D' - Du x α')/(1 - α') is defined as D1; (11): To A in Figure 4; (12): (Transparent); (13): (Intransparent); (14): D? x (1 - α') + D x α' is defined as D"; (15): The contents of the positions corresponding respectively to X and Y of pixel value buffer 8 are renewed with D"; (16): The contents of the positions corresponding respectively to X and Y of intransparent Z buffer 3 are renewed with z; (17): The contents of the positions corresponding respectively to X and Y of intransparent pixel value buffer 4 are renewed with D]

Figure 4

/8

【図4】

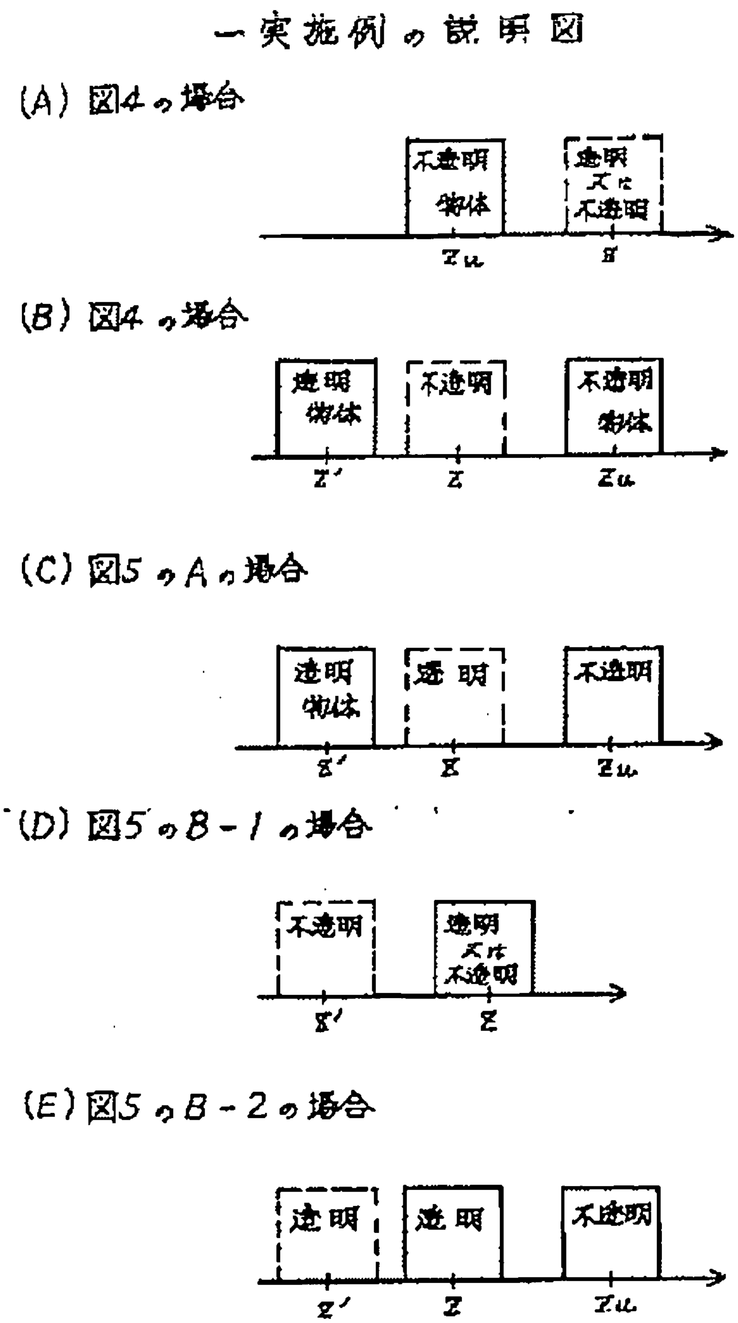
三次元画像処理フロー図



[(0): Three-dimensional image processing flow chart; (1): D? x (1 x α') + D x (1 - α) x α' is defined as D"; (2): α x α' is defined as α''; (3): D" x (1 - α'') + Du x α'' is defined as D"; (4): The contents of the positions corresponding respectively to X and Y of α buffer 9 are renewed with α''; (5): The contents of the positions corresponding respectively to X and Y of pixel value buffer 8 are renewed with D"; (6): (Transparent); (7): (Intransparent); (8): The contents of the positions corresponding respectively to X and Y of Z buffer 7 are renewed with Z; (9): The contents of the positions corresponding respectively to X and Y of α buffer 9 are renewed with α; (10): The contents of the positions corresponding respectively to X and Y of intransparent Z buffer 3 are renewed with Z; (11): The contents of the positions corresponding respectively to X and Y of intransparent pixel value buffer 4 are renewed with D; (12): (D' - Du x α')/(1 - α') is defined as D1; (13): D x (1 - α) + D1 x (1 - α') x α is defined as D"; (14): α x α' is defined as α''; (15): D" x (1 - α'') + Du x α'' is defined as D"; (16): The contents of the positions corresponding respectively to X and Y of the Z buffer are renewed with Z; (17): The contents of the positions corresponding respectively to X and Y of α buffer are renewed with α''; (18): The contents of the positions corresponding respectively to X and Y of pixel value buffer are renewed with D"; (19): To C in Figure 3]

Figure 5

【図5】

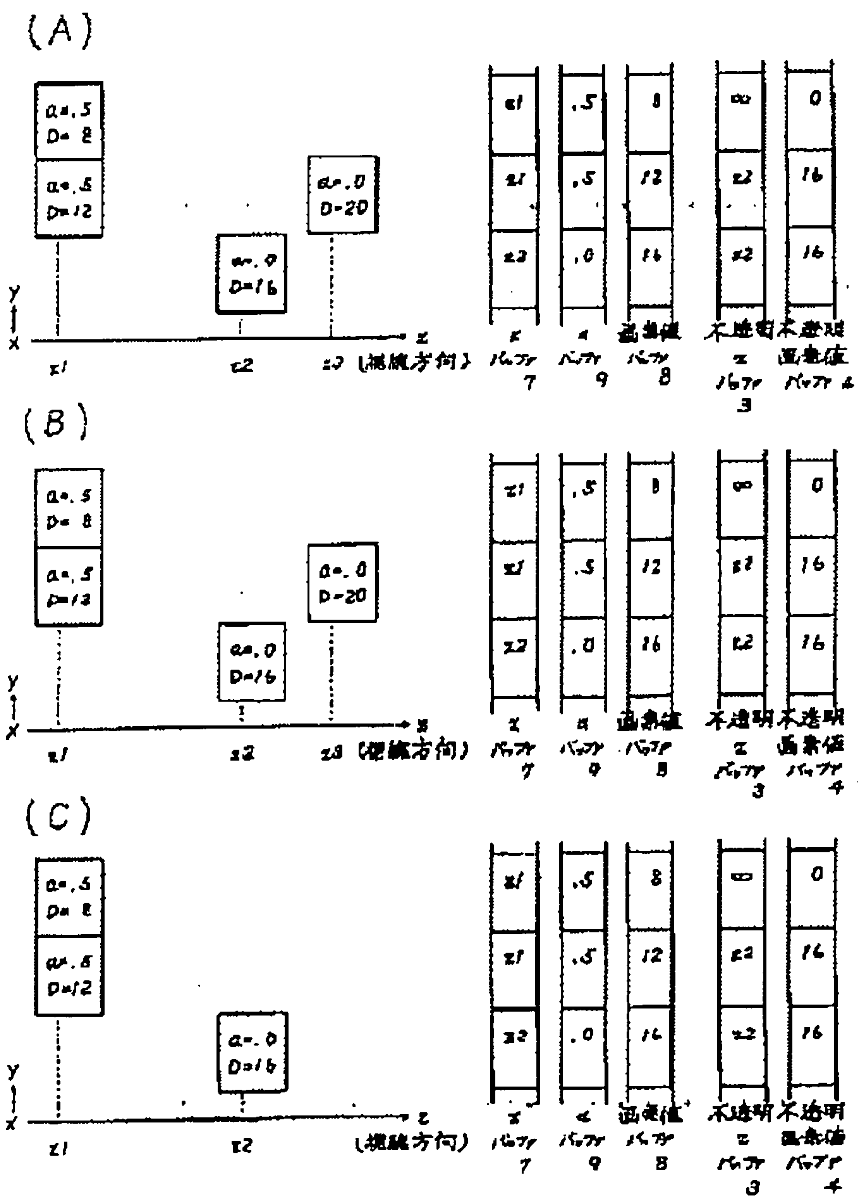

一実施例の説明図
(A) 図4の場合
不透明物体
透明又は不透明
Zu
Z
(B) 図4の場合
透明物体
不透明
不透明物体
Z'
Z
Zu
(C) 図5のAの場合
透明物体
透明
不透明
Z'
Z
Zu
(D) 図5のB-1の場合
不透明
透明又は不透明
Z'
Z
(E) 図5のB-2の場合
透明
透明
不透明
Z'
Z
Zu

[(0): Demonstrational diagram of an application example; (A): Case of Figure 4; (B): Case of Figure 4; (C): Case of A in Figure 5; (D): Case of B-1 in Figure 5; (E): Case of B-2 in Figure 5; (1): Intransparent object; (2): Transparent or intransparent; (3): Transparent object; (4): Intransparent; (5): Transparent]

Figure 6

【図6】

不透明物体の後に挿入される場合の説明図

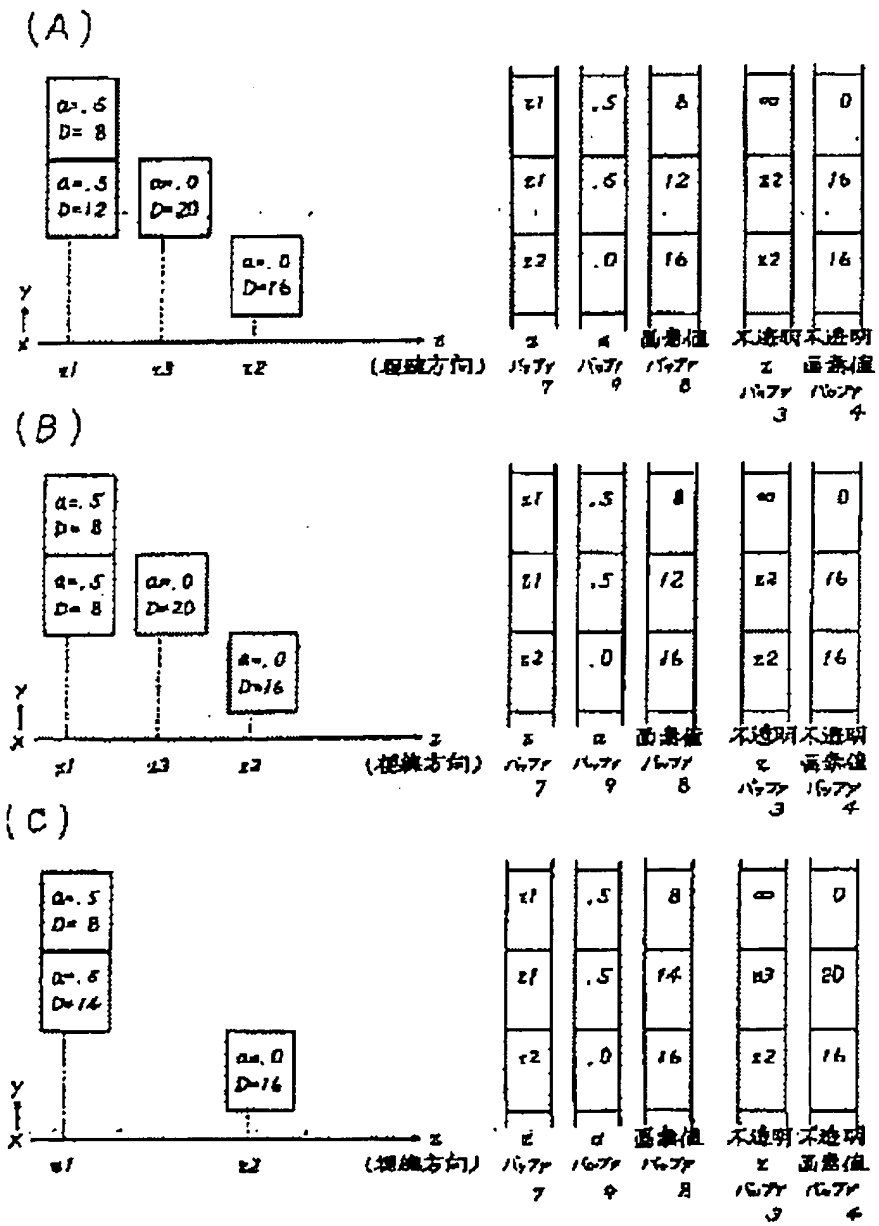


[(0): Demonstrational diagram pertaining to a case where an inserted member exists behind an intransparent object; (D): (Direction of perspective); (7): Z buffer; (9): α buffer; (8): Pixel value buffer; (3): Intransparent Z buffer; (4): Intransparent pixel value buffer]

Figure 7

【図7】

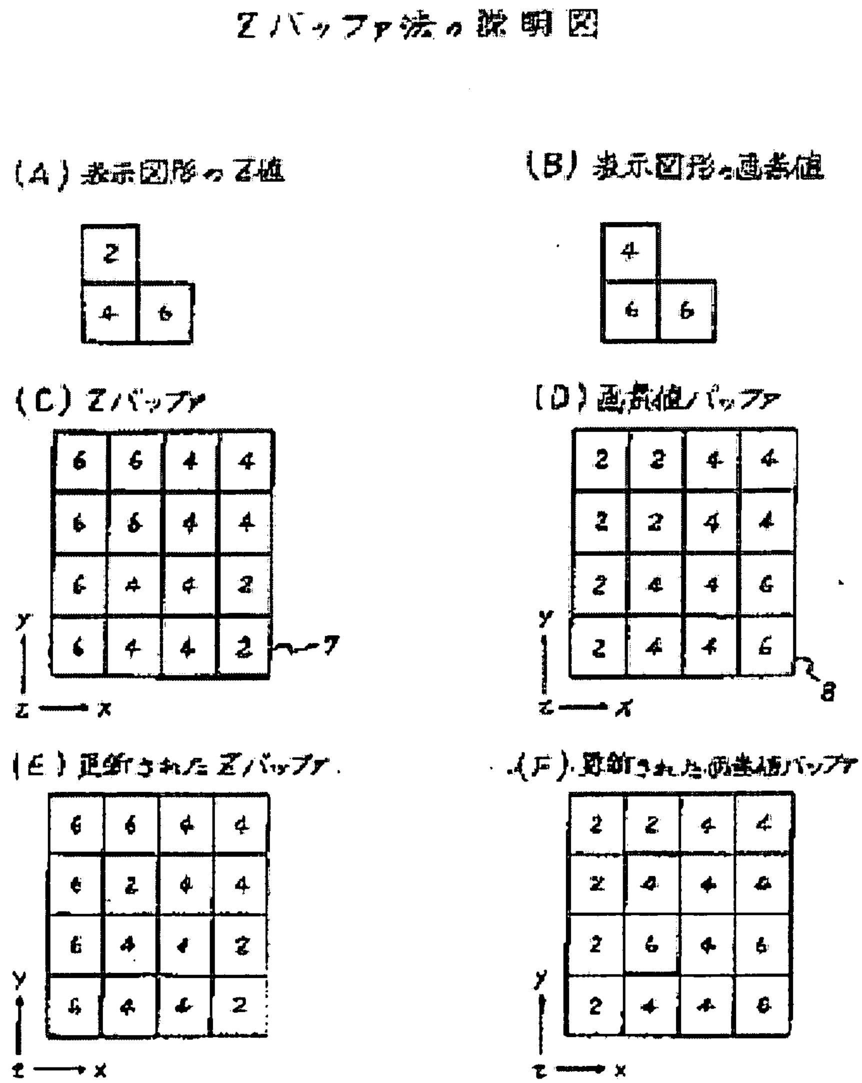
透明物体と不透明物体の間に挿入される場合の説明図



[(0): Demonstrational diagram pertaining to a case where an inserted member exists between a transparent object and an intransparent object; (D): (Direction of perspective); (7): Z buffer; (9): α buffer; (8): Pixel value buffer; (3): Intransparent Z buffer; (4): Intransparent pixel value buffer]

Figure 8 /10

【図8】



[(0): Demonstrational diagram pertaining to the Z buffer method; (A): Z value of displayed pattern; (B): Pixel value of displayed pattern; (C): Z buffer; (D): Pixel value buffer; (E): Renewed Z buffer; (F): Renewed pixel value buffer]

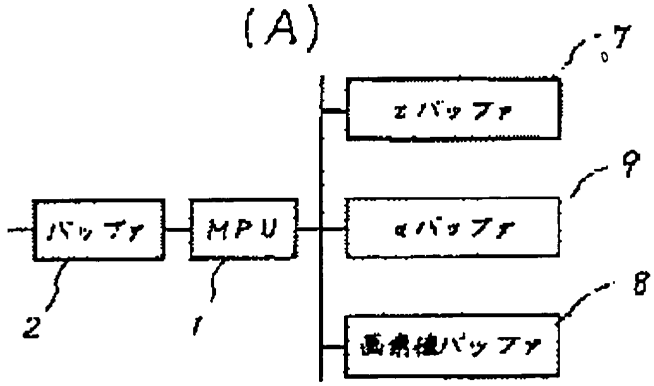
Figure 10

(A)

【図１０】

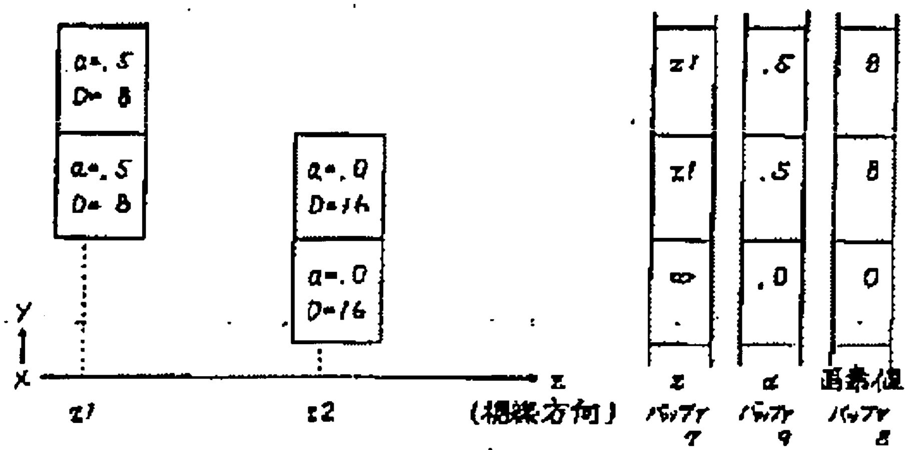
従来のアルファ・ブレンディング法の説明図

(A)



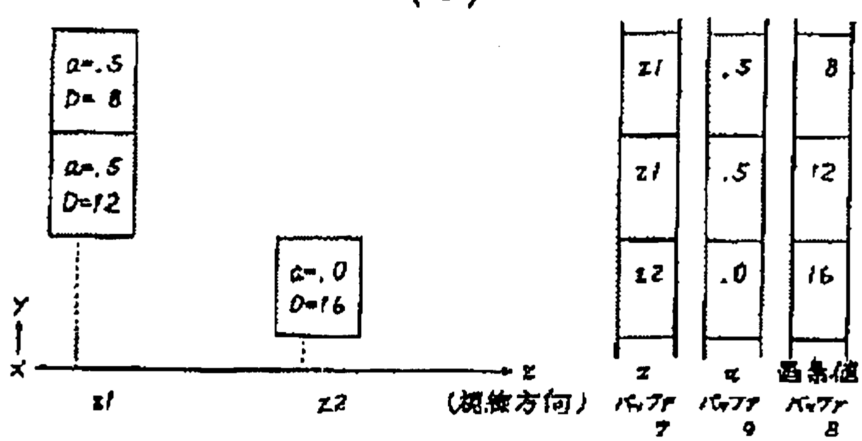
(B)

(B)



(C)

(C)

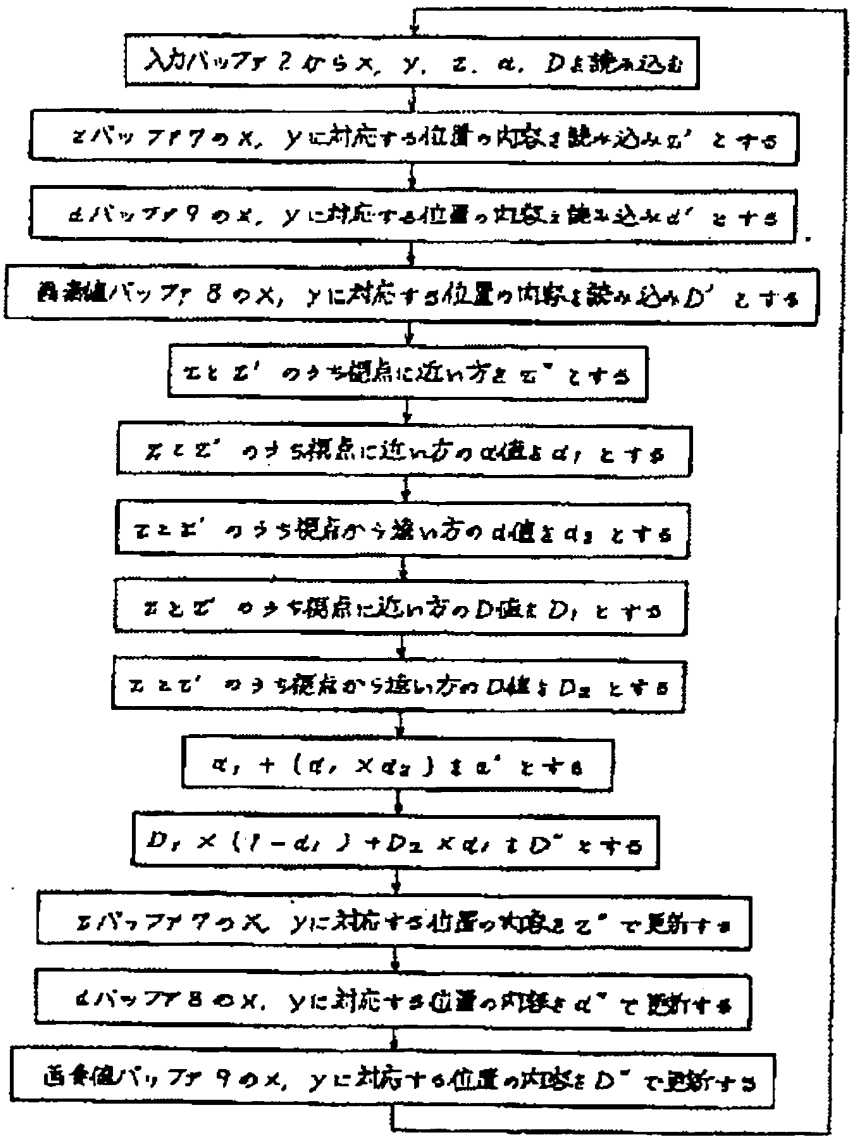


[(0): Demonstrational diagram pertaining to the alpha blending method of the prior art; (2): Buffer; (7): Z buffer; (9): α buffer; (8): Pixel value buffer; (D): (Direction of perspective)]

Figure 11 /11

【図11】

従来のアルファ・ブレンディング法の説明図



[(0): Demonstrational diagram pertaining to the alpha blending method of the prior art; (1): X, Y, Z, α, and D are encoded from input buffer 2; (2): The contents of the positions corresponding

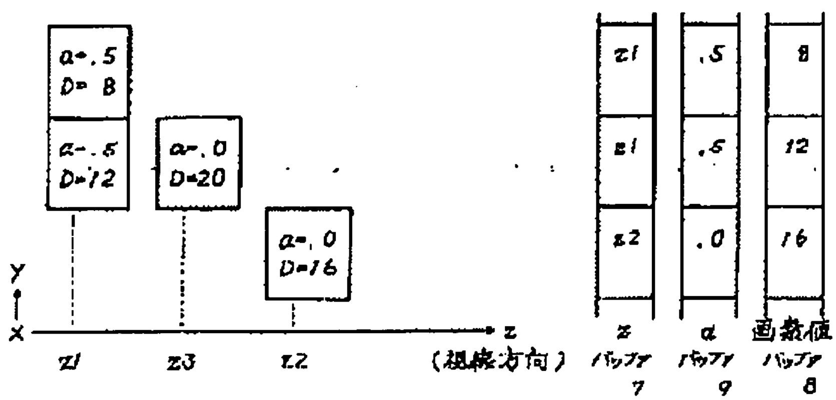
respectively to X and Y of Z buffer 7 are encoded and defined as Z'; (3): The contents of the positions corresponding respectively to X and Y of α buffer 9 are encoded and defined as α'; (4): The contents of the positions corresponding respectively to X and Y of pixel value buffer 8 are encoded and defined as D'; (5): Either member selected from between Z and Z' closer to the perspective is defined as Z"; (6): α value of either member selected from between Z and Z' closer to the perspective is defined as $\alpha 1$; (7): α value of either member selected from between Z and Z' farther from the perspective is defined as $\alpha 2$; (8): D value of either member selected from between Z and Z' closer to the perspective is defined as D1; (9): D value of either member selected from between Z and Z' farther from the perspective is defined as D2; (10): $\alpha 1 + (\alpha 1 \times \alpha 2)$ is defined as α''; (11): $D1 \times (1 - \alpha 1) + D2 \times \alpha 1$ is defined as D"; (12): The contents of the positions corresponding respectively to X and Y of Z buffer 7 are renewed with Z"; (13): The contents of the positions corresponding respectively to X and Y of α buffer 8 [sic: Presumably "9"] are renewed with α'';(14): The contents of the positions corresponding respectively to X and Y of pixel value buffer 9 [sic: Presumably "8"] are renewed with D"]

Figure 12

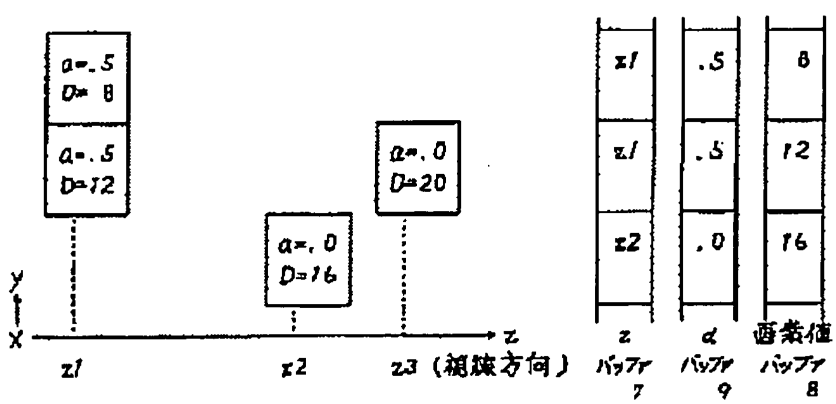
【図１２】

従来技術の問題点説明図

(A) Z1とZ2の物体間に物体が挿入された場合



(B) Z2の後に物体が置かれた場合

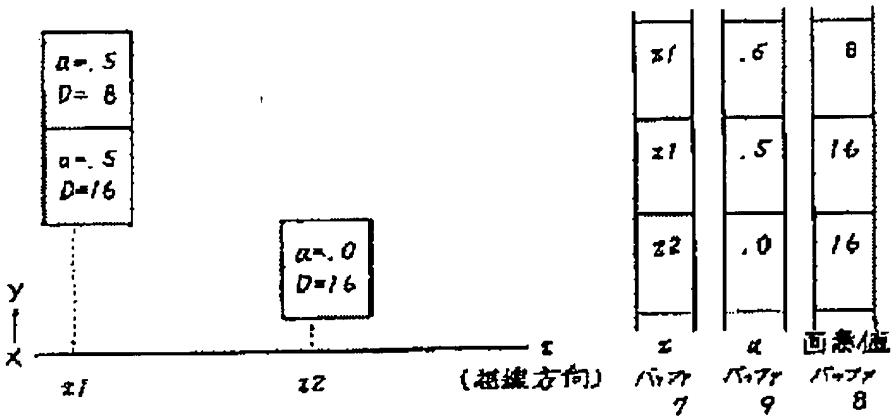


[(0): Demonstrational diagram provided for explaining the problems of the prior art; (A): Case where an object becomes inserted between objects of Z1 and Z2; (B): Case where an object is placed behind Z2; (D): (Direction of perspective); (7): Z buffer; (9): α buffer; (8): Pixel value buffer]

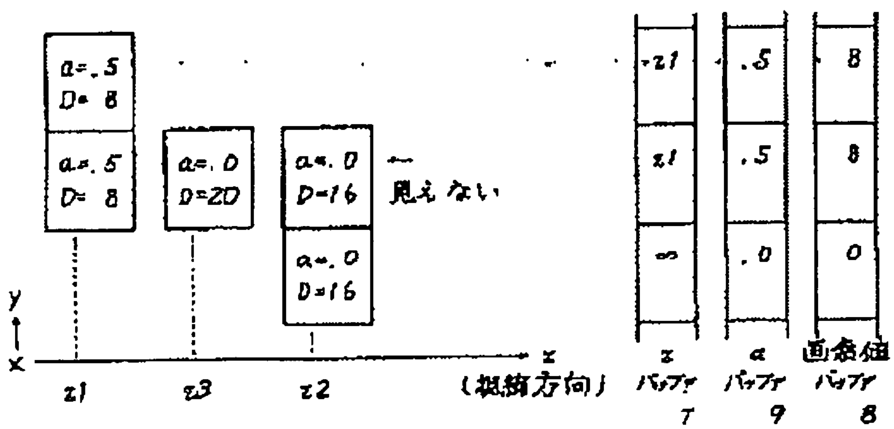
【図１３】

従来技術の問題点説明図

(A) 図12(A)(B)のブレンディング処理結果

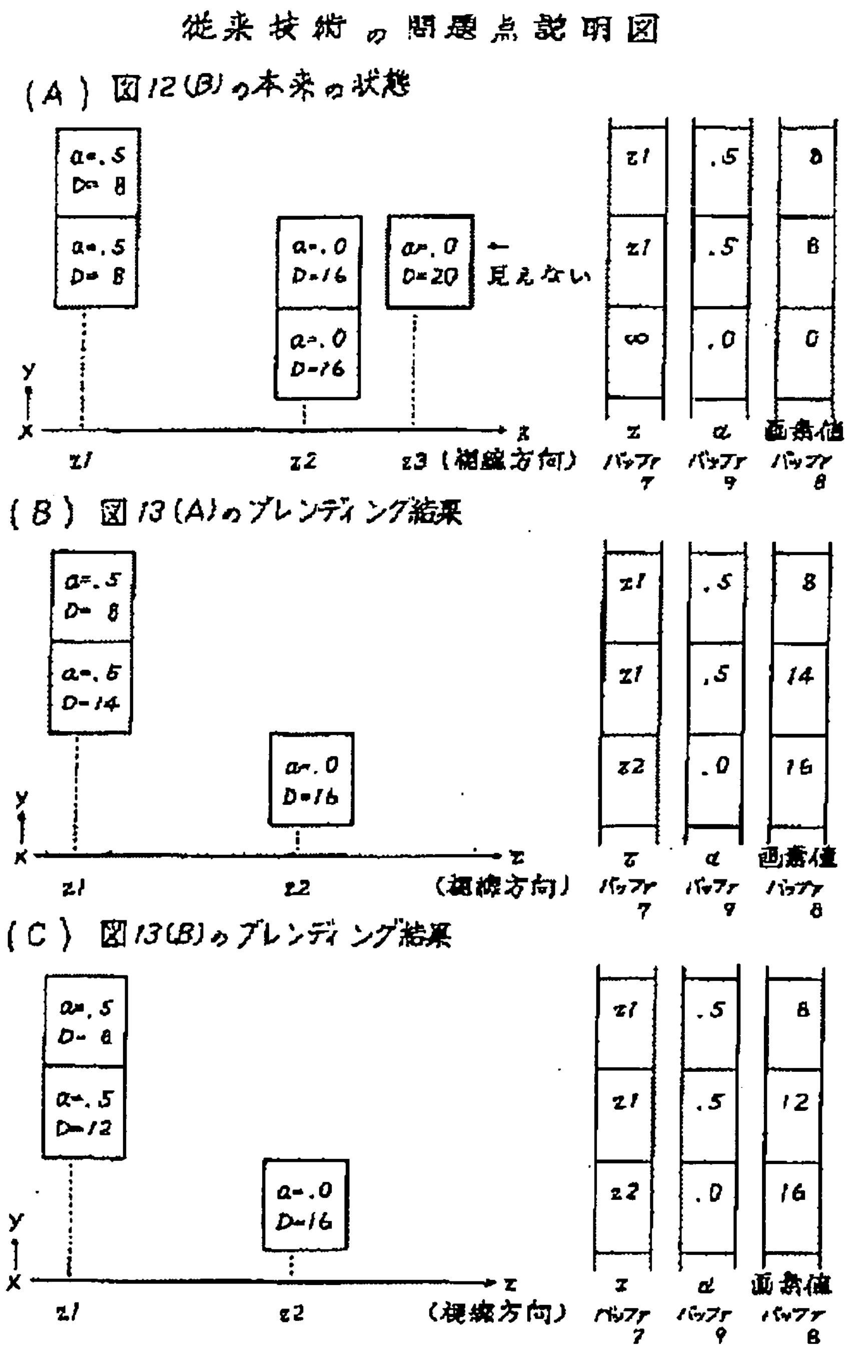


(B) 図12(A)の本来の状態



[(0): Demonstrational diagram provided for explaining the problems of the prior art; (A): Blending routine results of Figures 12 (A) and (B); (B): Original state of Figure 12 (A); (D): (Direction of perspective); (I): Invisible; (7): Z buffer; (9): α buffer; (8): Pixel value buffer]

Figure 14
【図１４】



[(0): Demonstrational diagram provided for explaining the problems of the prior art; (A): Original state of Figure 12 (B); (B): Blending results of Figure 13 (A); (C): Blending results of Figure 13 (B); (D): (Direction of perspective); (I): Invisible; (7): Z buffer; (9): α buffer; (8): Pixel value buffer]